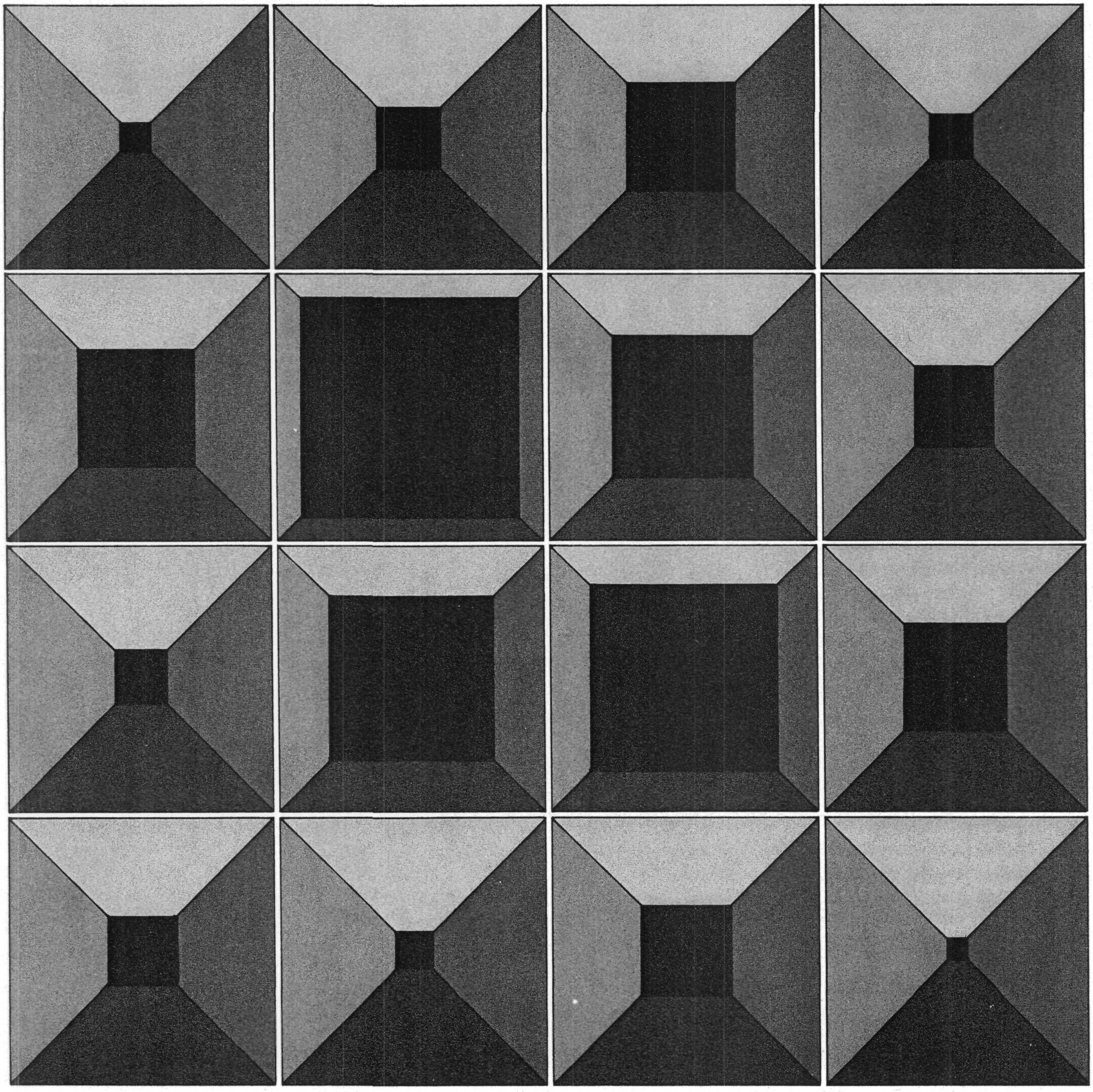
Naval Surface Combatants in the 1990s: Prospects and Possibilities

A CBO Study
April 1981

Congress of the United States
Congressional Budget Office



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NAVAL SURFACE COMBATANTS IN THE 1990s: PROSPECTS AND POSSIBILITIES

The Congress of the United States
Congressional Budget Office

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PREFACE

As the Congress considers the defense budget for fiscal year 1982, the size and cost of the naval shipbuilding program will be one of the most important issues. Of particular significance will be decisions concerning surface combatant warships. This report, prepared at the request of the House Committee on Armed Services, devotes primary attention to "battle group" surface combatants (that is, destroyers and cruisers capable of operating with the Navy's aircraft carrier battle groups).

Looking ahead to the late 1980s and early 1990s, the Navy faces a substantial drop in the surface combatant force level as ships currently in the fleet reach retirement age. Because of the long lead time required to design and build new warships, decisions made in the current budget deliberations can define and constrain the characteristics of ships delivered to the fleet in the 1990s. In accordance with CBO's mandate to provide objective and nonpartisan analysis, the report offers no recommendations.

This report was prepared by Peter T. Tarpgaard of the National Security and International Affairs Division of the Congressional Budget Office, under the general supervision of David S.C. Chu and Robert F. Hale. Edward A. Swoboda and Michael A. Miller of CBO's Budget Analysis Division provided valuable assistance in preparing the cost estimates. The author gratefully acknowledges the helpful comments and assistance of Robert Faherty, Damian Kulash, Nancy Swope, and Dov Zakheim of the CBO staff, and of Professor Ernst G. Frankel of the Massachusetts Institute of Technology, Dr. Lawrence Korb of the American Enterprise Institute for Public Policy Research, and Dr. Reuven Leopold of the Pratt & Whitney Aircraft Group. (The assistance of external reviewers implies no responsibility for the final product, which rests solely with the Congressional Budget Office.) Francis Pierce edited the manuscript; Jean Haggis prepared it for publication.

Alice M. Rivlin
Director

April 1981

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SUMMARY

The decade of the 1970s brought new challenges and uncertainties to the U.S. Navy. Accustomed since World War II to unequivocal dominance at sea, the Navy struggled in the 1970s with the pressures brought about by rapidly advancing technology, the block obsolescence of large numbers of World War II ships, and a vigorous challenge at sea from a Soviet navy growing in strength and confidence.

This struggle has continued into the 1980s. It is nowhere more evident than in that category of warships known as surface combatants--cruisers, destroyers, and frigates. Surface combatants are used in a variety of naval missions, including escorting aircraft carriers as part of a carrier battle group. During a major war, carrier battle groups are intended to be the Navy's primary instrument for gaining control of the seas and for attacking the enemy base structure and forces from the sea. Frontal assaults against Soviet homeland bases would almost certainly encounter stiff resistance from Soviet naval and air forces. Battle groups might also be required to confront additional, although probably less formidable, threats distributed widely over the world's oceans.

Additional tasks undertaken by surface combatants include their employment in surface action groups and as escorts for amphibious forces, underway replenishment groups, and convoys. Surface action groups are naval strike groups that do not contain an aircraft carrier. They are used today in the Middle East and the Carribbean, and could provide forces responsive to other crises in the Third World. Amphibious forces invade land areas from the sea. Underway replenishment groups replenish fuel, ammunition, and stores for warships at sea and are essential for sustained naval operations away from home waters. Merchant ship convoys will almost certainly require vigorous protection against enemy interdiction, as they have in past wars. All of these functions will require surface combatants beyond those needed for carrier battle groups.

Looking ahead to the late 1980s and early 1990s, the Navy faces a substantial drop in the surface combatant force level as the ships delivered in the late 1950s and early 1960s reach

retirement age. At the same time, the challenge posed by the forces of potential adversaries has continued to grow.

In addressing this challenge, several related questions must be considered:

- o How large a surface combatant force will the Navy have in the 1990s, given the number of new ships already authorized and the ships now in the fleet that will not yet have reached the end of their service lives?

- o How might recent technological developments affect the likely role of future surface combatants?

- o Given these technological developments, and alternative views of naval strategy, what mix of surface combatants might be considered within whatever budget level the Congress selects?

These questions are the focus of this paper.

CURRENT FORCES

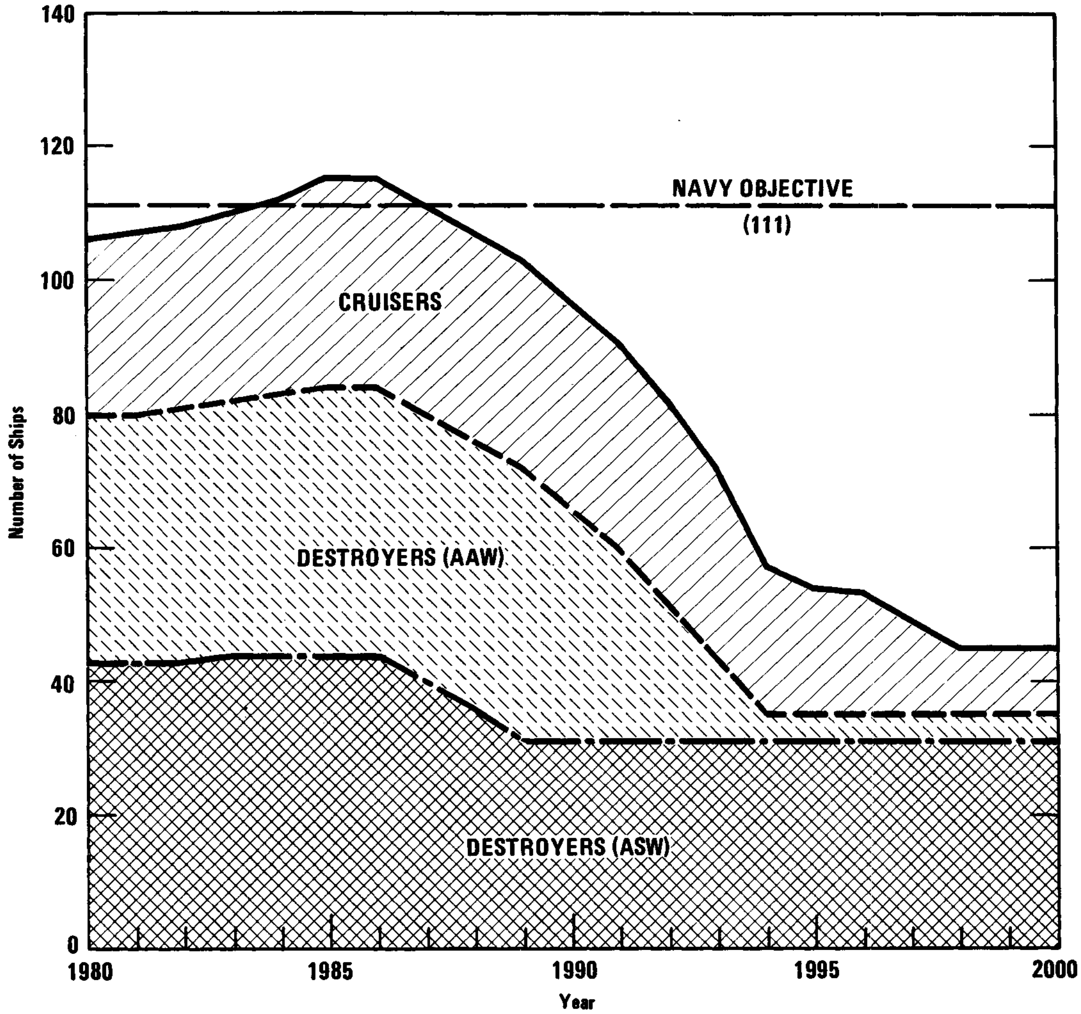
Surface combatants are currently classed as either cruisers, destroyers, or frigates depending upon their general size and capabilities. Cruisers and destroyers are also classed by the Navy as "battle group" surface combatants and are intended for use in offensive strikes with aircraft carrier battle groups. Frigates, smaller and less capable ships, are normally intended for less demanding missions, such as convoy escort and protection of underway replenishment ships.

Impending Decline in Numbers of Battle Group Surface Combatants

The Navy perceives the most acute future deficiencies as occurring in the battle group category, since many cruisers and destroyers now in the fleet will reach retirement age in the period 1985-1995. The number of cruisers and destroyers will decline from their present level of 116 (nine of which are still under construction) to about 45 by the end of the century in the absence of further ship construction (see Summary Figure 1). Just maintaining the current size of the cruiser/destroyer force will require an average delivery rate of about 6.5 new ships per year during the 10-year period 1987-1997, significantly higher

Summary Figure 1.

Projected Force Levels for Battle Group Surface Combatants



Note: Includes authorizations through fiscal year 1981. Objective of 111 was specified to the Congress in Navy testimony of February 1980. Testimony given to the Congress in March 1981 suggested a new, higher level of 137.

than the average rate of 3.3 new cruisers and destroyers authorized per year during the past decade.

The Navy believes that at least 111 battle group surface combatants are required to support its mission requirements--a minimum, the Navy stresses, that is adequate only under optimistic assumptions about a future worldwide war. Moreover, these minimum requirements may not fully reflect needs brought about by added peacetime deployment requirements, such as the current deployment in the Indian Ocean.

Force level requirements from the Navy's 1980 testimony, the basis of the most recent Congressional shipbuilding decisions, are used in this report, but the new Administration's higher goals are also considered.

Upgrading Needed

Although a warship's hull and machinery can be built to last for 30 years, its combat systems usually become obsolete much sooner and must be updated periodically to remain effective. In the 1980s, many of the current surface combatants will enter their third decade of service and will need modernization, particularly for their anti-air warfare (AAW) missile systems. The Navy has developed three combat system upgrade programs for ships in this category: the CG/SM-2 Upgrade, the New Threat Upgrade, and the DDG-2-Class Upgrade. The CG/SM-2 Upgrade and New Threat Upgrade will enable older ships to use the Navy's new Standard SM-2 missile and will provide particularly dramatic capability improvements at a relatively modest cost. For example, the CG/SM-2 Upgrade and New Threat Upgrade would give the 10 ships of the DDG-37 class a modern, long-range AAW capability, exceeding the AAW range of even the new CG-47 cruiser. These 10 ships could be upgraded for a total cost of about $260 million, or one-fourth the procurement cost of a single CG-47 cruiser.

SURFACE COMBATANTS IN THE FUTURE: NEW TECHNOLOGIES AND NEW CAPABILITIES PORTEND A GROWING ROLE

Once the centerpiece of naval forces, the surface combatant was superseded in World War II by the aircraft carrier and submarine as the primary naval striking arm. Since that time, surface combatants have served primarily as escorts, supporting aircraft carrier operations and defending noncombatants from attack. Now, new technological developments hold out the prospect of

substantially improved capabilities for surface combatants--capabilities that will not only improve their present escort capabilities but may also restore some degree of independent strike capability to them.

These developments include:

- <u>Cruise missiles</u>, which will give surface combatants a long-range offensive strike capability against both ship and land targets;

- <u>Towed-array sonars</u>, which will permit detection of submarines at long range;

- <u>Helicopters and/or vertical/short take-off and landing (V/STOL) aircraft</u>, which will provide surveillance and targeting for long-range cruise missiles and a means of prosecuting long-range submarine contacts; and

- <u>Anti-air warfare improvements</u>, which will significantly strengthen capabilities against both cruise missiles and high-performance aircraft, making future surface combatants much more dangerous to attack.

OPTIONS FOR THE FUTURE: CHOICES REFLECT COST AND STRATEGY

In considering future naval shipbuilding programs, the Congress not only must consider the perennial problem of how to reconcile escalating costs with ship capability but must also make judgments about future naval strategy and how the Navy might be used in future crises and conflicts.

The Navy believes that the most efficient way to gain and maintain control of the seas is to destroy those hostile forces capable of challenging that control. It would use carrier battle groups as the primary instrument of such offensive action. The capabilities required by these battle groups, and therefore by the surface combatants that operate with them, are determined by the maximum resistance they might encounter--that is, resistance to an offensive assault against Soviet homeland bases.

This strategy, however, is by no means the only one the Navy may be called upon to execute in the future. Depending upon the circumstances at hand, the national command authority may find it advisable (because of the nature of the crisis, the disposition of

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Soviet forces, vulnerability to nuclear attack, or risk of escalation) for the Navy to pursue some strategy other than a frontal assault on Soviet home bases. The Navy may be required to face a distributed threat by Soviet and/or other naval forces that would require a different mix of ships, including a sufficient number of surface combatants to protect U.S. interests over a relatively long period of time in distant waters. Indeed, recent events in the Middle East have been of this nature, straining the Navy's resources with demands for further standing force deployments.

Alternative Ship Types

With these considerations in mind, four representative surface combatants may be used to illustrate a range of alternatives with respect to modern surface combatant ship designs. These are:

- Nuclear Cruiser (CGN-42). A nuclear-powered warship employing the best weapons and sensors currently available, the CGN-42 would have the operational flexibility inherent to the unlimited steaming range of nuclear power. It would have the new, high-capability AEGIS AAW system, offensive cruise missiles, LAMPS III helicopters, a high-power active sonar and a towed-array passive sonar for antisubmarine warfare (ASW), a large missile capacity (122 missiles) in the new vertical launch system (VLS), and the latest in command, control, and communications equipment. All these features would give the ship excellent capabilities across a broad spectrum of naval missions. The CGN-42 would be an expensive ship, with an acquisition cost of about $1.34 billion--including nuclear fuel equivalent to about 3 million barrels of oil. 1/

- AEGIS Cruiser (CG-47). A smaller, conventionally powered cruiser, the CG-47 has essentially the same formidable combat system as the nuclear cruiser but lacks the unlimited steaming range of nuclear power. Ships of this class are currently being procured by the Navy at an estimated cost of about $1.02 billion per ship.

1/ All costs in this summary are in constant fiscal year 1982 dollars.

- Battle Group Destroyer (DDGX). A new surface combatant design, the DDGX is being developed by the Navy primarily for operations with aircraft carrier battle groups. Its combat system will emphasize the AAW and ASW capabilities currently believed by the Navy to be most necessary for carrier battle group operations. Its AAW system will have a powerful AEGIS-like radar, and its ASW system will be oriented toward active sonar screening using the large, low-frequency SQS-53 sonar. The estimated procurement cost of the DDGX is about $550 million per ship.

- Open Ocean Destroyer (DDGY). A hypothetical surface combatant capable of operating with carrier battle groups, the DDGY would be less optimized for that mission in the interest of providing it with a better capability for independent, open-ocean operations. It would have a less powerful air search radar and a less powerful active sonar than the DDGX, but would be equipped with LAMPS III helicopters, a towed-array sonar, and a large-caliber gun. Somewhat smaller but faster than the DDGX, the DDGY would have a lower unit procurement cost, estimated at about $375 million.

Specific characteristics of these alternative ship types are shown in Summary Table 1.

Alternative Shipbuilding Programs

Choosing which ships to build among these alternatives depends upon one's perceptions of future naval combat and wartime strategy.

Four packages of the ships discussed above consistent with different perceptions of future naval strategies are presented in Summary Table 2. Each package, or program option, is structured to have approximately the same 10-year (1986-1995) investment cost--about $33 billion. This is the estimated cost of the program recommended by the Navy in testimony to the Congress in 1980, presented here as Option II. Life-cycle costs of the program alternatives vary only about 10 percent about the mean for all options, with Option I having the lowest life-cycle cost and Option IV the highest. All options assume procurement of at least 18 CG-47-class ships (three options have 24) and would support at least the six two-carrier battle groups envisioned in the 1980 Navy testimony.

SUMMARY TABLE 1. CHARACTERISTICS OF ALTERNATIVE SHIP TYPES

	Nuclear Cruiser (CGN-42)	AEGIS Cruiser (CG-47)	Battle Group Destroyer (DDG X) a/	Open Ocean Destroyer (DDGY) b/
Displacement (tons)	12,000	9,100	6,000	5,000
Maximum Speed (knots)	30+	30	29	30
Endurance Speed (knots)	--	20	18	20
AAW Systems				
Search radar	SPY-1	SPY-1	MFAR	3-D c/
Fire control radar	4 MK99	4 MK99	2 MK99 or 2 Agile Beam	2 Agile Beam d/
Launcher system	VLS	VLS	VLS	VLS
Missile capacity	122	122	90	90
Missile type	SM-2	SM-2	SM-2	SM-2
ASW Systems				
Towed-array sonar	SQR-19	SQR-19	None	SQR-19
LAMPS-compatible	Yes	Yes	Yes	Yes
Number of aircraft	Two	Two	None	Two
Hull-mounted sonar	SQS-53	SQS-53	SQS-53	SQS-56
ASW weapons	ASROC/MK32 Tubes	ASROC/MK32 Tubes	ASROC/MK32 Tubes	ASROC/MK32 Tubes
ASuW Systems				
Missiles	Tomahawk (TASM)	Tomahawk (TASM)	Tomahawk (TASM)	Tomahawk (TASM)
Guns	Two 5"/54	Two 5"/54	None	One 155mm (6")
Land Attack Systems				
Missiles	Tomahawk (TLAM)	Tomahawk (TLAM)	Tomahawk (TLAM)	Tomahawk (TLAM)
Guns	Two 5"/54	Two 5"/54	None	One 155mm (6")
Estimated Cost (millions of fiscal year 1982 dollars)	$1,340	$1,018	$550	$375

a/ A final decision on the configuration of the DDG X has not yet been made. The characteristics listed above may be changed by the Navy as the design process progresses.

b/ For DDGY weight and cost rationale, see Appendix D.

c/ SPS-48E 3-D and SPS-49 2-D air radars as used on the latest U.S. ships supplemented by horizon and high-elevation search by agile beam fire control radars. Later units might have a new-generation air search radar.

d/ Agile beam is used here as a generic term that includes such specific concepts as the Terminal Engagement Radar (TER) or Flexible Adaptive Radar (FLEXAR). This system would be capable of simultaneously tracking and engaging multiple targets while supplementing the air search function in the horizon and zenith areas.

SUMMARY TABLE 2. ILLUSTRATIVE $33 BILLION 10-YEAR PROGRAMS FOR SURFACE COMBATANT WARSHIP CONSTRUCTION, FISCAL YEARS 1986-1995

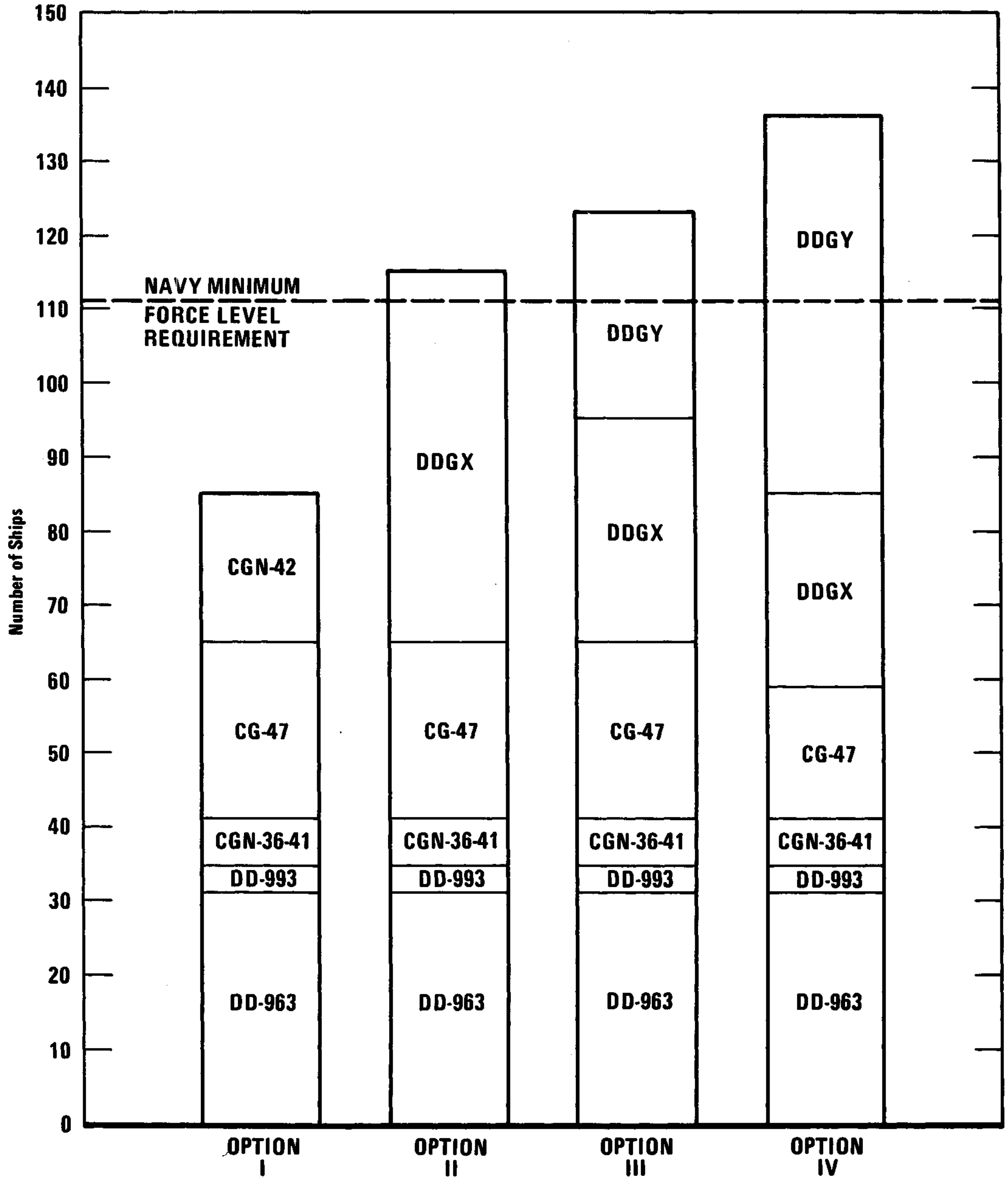
Option	New Ships Authorized				Percent of Current Force Level at Sea in Year 2000
	Ship Type	In 1985 or Earlier	In 1986 Through 1995	Through 1995	
Option I:					
Emphasize	CGN-42	0	20	20	77
Capability	CG-47	18	6	24	
				44	
Option II:					
Emphasize Battle	CG-47	18	6	24	105
Group Operations	DDG X	1	49	50	
				74	
Option III:					
Balance Battle	CG-47	18	6	24	113
Group and Other	DDG X	1	29	30	
Mission Emphasis	DDGY	0	29	29	
				83	
Option IV:					
Emphasize Broad-	CG-47	18	0	18	124
Ocean Distributed-	DDG X	1	25	26	
Force Operations	DDGY	0	51	51	
				95	

The four options have different consequences as to the number and types of ships that would be at sea in the fleet in the year 2000. The force level and force structure resulting from each of the options is displayed in Summary Figure 2. The dashed line indicates the Navy's minimum force level requirement as identified in 1980 Navy testimony. Summary Table 3 shows the mission support implications of each option, assuming that priority is given to supporting six two-carrier battle groups.

Option I. The advocate of Option I accepts the Navy's view that offensive strikes into enemy waters will be the key to victory in the future and believes only the most capable ships

Summary Figure 2.

Battle Group Surface Combatant Force Levels and Structures in the Year 2000: Four Equal-Cost Alternatives



SUMMARY TABLE 3. MISSION SUPPORT IMPLICATIONS OF ALTERNATIVE PROGRAM OPTIONS IN THE YEAR 2000

Mission Capability	Option I	Option II	Option III	Option IV
Number of Two-Carrier Battle Groups Supported	6	6	6	6
Number of Surface Action Groups Supported	0	3	4	5
Number of Amphibious Escort Ships	9	11	13	18
Number of Underway Replenishment Escort Ships	24	32	32	32
Number of Convoy Escort Ships	66	66	68	70

will be equal to that task. Although sympathetic to the need for more ships, the advocate of Option I is skeptical of claims that capability compromises in the interest of cost reduction yield more overall fleet effectiveness. The advocate of Option I believes that quality must govern, despite the fact that more ships could be bought at any given level of investment if some less expensive ships were procured. This option would produce sufficient ships to form six well protected two-carrier battle groups. There would not be enough ships, however, to form any surface action groups or to provide the number of escorts for amphibious groups, replenishment groups, and convoys recommended by the Navy in its 1980 testimony.

Option II. The advocate of Option II also accepts the Navy's offensive strike strategy and wants the best capabilities available for surface combatants, but he regards the "no-compromise-on-capability" approach of Option I as unrealistic and likely to result in a dangerously small Navy. He believes it is not only possible but necessary to make judicious choices on warship features that will provide ships adequate to their mission and sufficiently affordable so as to be procured in adequate numbers.

In making such choices, the advocate of Option II believes that battle group operations against intensive enemy opposition in a forward area represent the proper reference scenario. Thus, he favors buying the DDGX, which, though lacking the unlimited steaming range and top-line combat suite of the CGN-42, has the capabilities needed for battle group operations and, being substantially less expensive than the CGN-42, can be procured in larger numbers for any given level of investment. This option was favored by the Navy in its testimony to the Congress in 1980, and meets the force level objectives reflected in that testimony.

Option III. The advocate of Option III agrees with the concept of offensive battle groups and supports the DDGX as contributing to battle group capability. He perceives a variety of other tasks for the Navy, however, such as extended patrol and presence operations in the Third World, where concentrated battle groups may not be the most efficient or appropriate application of naval forces. These tasks might be more likely to involve wide-ranging operations against a distributed threat rather than a single concentrated force. He therefore supports putting some resources into the DDGY, which, though capable of battle group operations, is oriented more toward independent, open-ocean operations than the DDGX. This, he believes, will produce a better balance of capabilities against the uncertainties of the future than procurement of only the DDGX. As shown in Summary Table 3, this option provides sufficient ships to form four surface action groups, in addition to the six battle groups and the escort forces.

Option IV. The advocate of Option IV also recognizes the importance of tactical air power and supports the concept of carrier battle groups. He is less convinced than the advocates of the previous options, however, that a frontal assault by battle groups in enemy waters is the best strategy for a future war. He believes that, for a variety of reasons, it is more likely that a future naval war will involve worldwide operations against a much more distributed threat than the concentrated forces of the battle-group scenario. Although favoring the DDGX program as necessary to support battle group operations in the 1990s, he perceives a higher utility for more numerous, independently operating naval groups and therefore supports putting relatively more emphasis on the DDGY. This approach, he believes, would provide not only more ships for the same investment, but more ships of a kind most likely to be needed in the future. Option IV provides sufficient ships to form five surface action groups in

addition to the six battle groups, and provides at least seven more escorts than any other option.

LARGER NAVAL FORCE LEVELS: SOME IMPLICATIONS

The options presented above reflect the Navy's requirements and force level planning as presented to the Congress in 1980 testimony. The $33 billion assumed investment cost for each option is CBO's estimate of the 10-year investment cost of the program recommended by the Navy in that testimony (Option II).

Recently the Reagan Administration has announced its intention to pursue a more ambitious naval program, including building and maintaining a force of 15 aircraft carriers. 2/ The program proposed by the new Administration includes higher force level goals for other types of ships as well, including a new goal of 137 battle-group-capable surface combatants.

Of the options discussed above, only Option IV provides enough ships to support seven battle groups, while still meeting the Navy's other mission requirements. Programs to support seven two-carrier battle groups using the force structure approach taken by the other options would require an even higher level of investment, with about $50 billion being required over the 10-year period as against $33 billion used here. At any level of investment, however, whether $33 billion, $50 billion, or some other amount, these options still illustrate two key principles: the ship capabilities needed depend upon one's view of future naval strategy, but an emphasis on high-cost ships reduces the force levels that can be achieved within a given budget.

SURFACE COMBATANTS FOR THE 1990s: A PROBLEM FOR TODAY

Although the projected decline in battle group surface combatant force levels will not occur until the 1990s, even

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2/ See "FY 1982 Shipbuilding and Conversion Budget Request," statement of Vice Admiral William H. Rowden, USN, Deputy Chief of Naval Operations for Surface Warfare, before the Subcommittee on Seapower and Strategic and Critical Materials, House Committee on Armed Services (March 25, 1981; processed). See also "Interview with the Secretary of the Navy," Sea Power (March 1981), pp. 17-30.

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if present shipbuilding policies are maintained, the long lead time required to design and build modern warships means that replacement programs must begin well before the required delivery times. This is true not only for the ships themselves but also--and most particularly so--for the combat system components that they will carry. Thus, research and development decisions made in the next year by the Administration and by the Congress can define and constrain ship procurement options in the mid-1980s and, consequently, the number of ships delivered to the fleet in the 1990s. For Option II to be a real shipbuilding alternative in 1986, funding for DDGX design and combat system development must be provided in fiscal year 1982. Similarly, for Options III and IV to be real alternatives, research and development funding for DDGY design and combat system development must also be provided. This would probably require funding of about $100 million to $150 million per year depending upon the number and status of ongoing projects.

In addition, the ships currently in the fleet will require periodic upgrading to maintain their effectiveness in a rapidly changing technological environment. This will require continuing research and development funding for modernization programs, such as the CG/SM-2 Upgrade and the New Threat Upgrade, as well as funds actually to accomplish the upgrades when the new systems become available.

CHAPTER I. INTRODUCTION

Surface combatants, always an important element of naval forces, are now the subject of especially intense interest in the U.S. Navy. Although major surface combatants--battleships and cruisers--were the centerpiece of fleet battle forces in the years preceding World War II, ships of this category have declined in relative importance since that time, with dominance passing to aircraft carriers and nuclear submarines. Since World War II, surface combatants have been used largely in escort and support roles--vital functions to be sure, but clearly a step removed from their former glory. Now the surface combatant appears to be in the path of several converging technological trends that could produce dramatic new capabilities--a development that would place the surface combatant firmly back in the front rank of naval strike forces.

Cruise missiles, ship-based helicopters, new antisubmarine sensors, and dramatic improvements in anti-air warfare systems are among the factors that have contributed to this resurgence. But technology cuts the other way as well; these and other developments in the hands of potential adversaries can be expected to produce new or more dangerous threats to future U.S. surface combatants. Providing for well-considered programs for building surface combatant ships and for a vigorous research and development program to support those ships will be an important undertaking for the Congress in fulfilling its constitutional responsibility to "provide and maintain a Navy."

Given the high procurement cost of modern warships, a sustained program to replace and improve the current surface combatant force will be a very large and continuing budget item. Investment costs alone for each of the program alternatives considered in this report will total approximately $33 billion over the next 10 years. 1/ In addition to investment costs, funding must be provided for continuing research and development on new surface combatant construction and fleet upgrade programs.

1/ All costs in this paper, unless otherwise specified, are in constant fiscal year 1982 dollars.

To these expenses must be added the operating costs for the ships, which, over their service life, can total as much or more than their investment cost.

In its deliberations on this issue, the Congress will be considering several related questions:

- How large a surface combatant force will the Navy have in the 1990s, given the number of new ships already authorized and the ships now in the fleet that will not have reached the end of their service lives?

- How might recent technological developments affect the likely role of future surface combatants?

- Given these technological developments, and alternative views of naval strategy, what mix of surface combatants might be considered within whatever budget level the Congress selects?

These questions are the focus of this paper.

Chapter II assesses the current naval surface combatant force in terms of its size and capabilities, and examines how force levels are projected to change in the future. These future force levels are then compared to the Navy's current statement of its requirements. The chapter also discusses several important modernization programs that have been proposed by the Navy to upgrade current surface combatants--programs that will affect fleet capabilities more immediately.

Chapter III addresses the contribution of surface combatants to overall naval force effectiveness and assesses their likely role in the future. It considers several technological developments that could lead to significant improvements in surface combatant capabilities.

Chapter IV describes four alternative shipbuilding programs for the period 1986-1995 that respond to differing projections of future surface combatant requirements.

Force level requirements presented in the Navy's 1980 testimony, which served as the basis of the most recent shipbuilding decisions by the Congress, are used in this report. Some implications of more ambitious force level goals, just proposed by the new Administration, are discussed in Chapter IV.

CHAPTER II. U.S. SURFACE COMBATANTS: PROSPECTS FOR THE 1990s

NUMERICAL TRENDS

A widely used and unquestionably significant indicator of naval strength is the number of ships available in the fleet. Despite the many caveats that must attend simple numerical comparisons--caveats as to individual ship capability, training and readiness levels, tactics, mission requirements, etc.--such comparisons can be a useful first-order indicator of force trends.

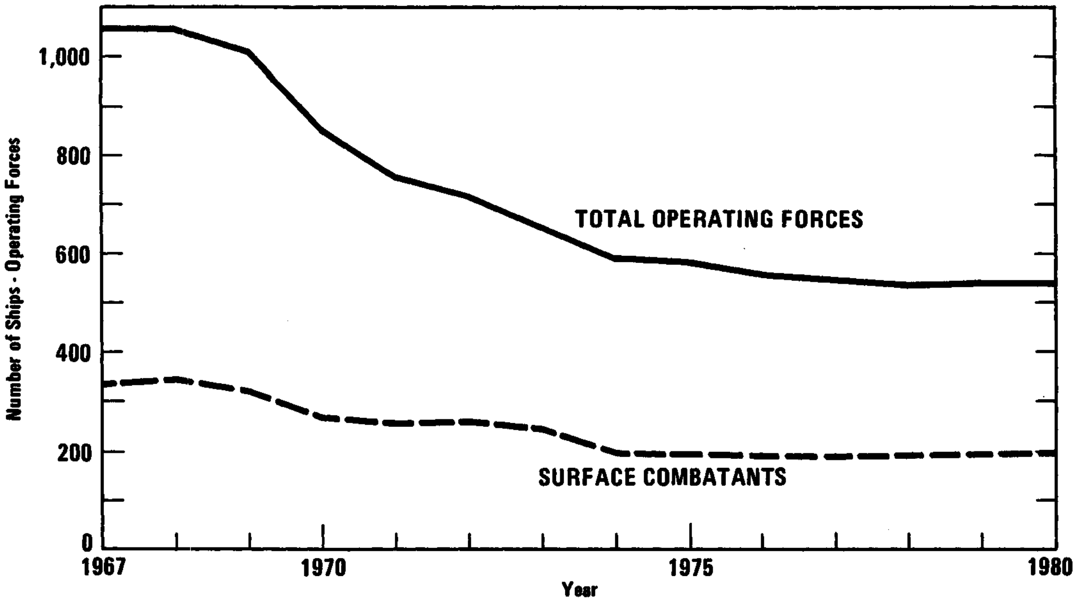
Current Force Levels

The number of ships in the U.S. Navy declined sharply during the six-year period 1968-1974, dropping from 1,055 to 587 units. The surface combatant segment followed a similar trend, declining from 339 units in 1968 to 198 units in 1974. This decline resulted in large part from the retirement of many 25- to 30-year-old World War II-era ships that had reached the end of their service lives. Since 1974, force levels have remained fairly constant, with total ship operating forces (as of September 30, 1980) at 538 units, of which 193 are surface combatants. These trends are shown in Figure 1.

Oceangoing surface combatants are usually designated as cruisers, destroyers, or frigates depending upon their size and capabilities. Although cruisers of the World War II era were distinctly different in design from destroyers (cruisers carried extensive armor and substantially heavier armament), today's surface combatants can be viewed as lineal descendants of the destroyer type, scaled up or down in size to accommodate their weapons suite (the aggregate collection of weapons and sensor systems) and ship performance requirements. Cruisers are the largest and most capable of the three types; destroyers are usually smaller and less capable; and frigates are the smallest and least capable ships. Classifications are often somewhat arbitrary, however, since a warship's effectiveness can vary more with its age than with its size. 1/

1/ Before 1975, the term "frigate" was used to designate a ship larger than a destroyer but smaller than a cruiser. In 1975,

Figure 1.
U.S. Naval Force Level Trends: Total Operating Forces and Surface Combatants, 1967-1980



New Authorizations

Throughout most of the 1960s, naval ship production proceeded at a substantially higher pace than the level that has prevailed in recent years. Toward the end of the decade, however, steadily shrinking shipbuilding budgets, together with increasing shipbuilding costs, resulted in a sharp decline in new ship authorizations. This trend is illustrated in Figure 2, which shows the number of naval ships authorized for construction each year over the fiscal year 1962-1980 period. Throughout the 1970s and

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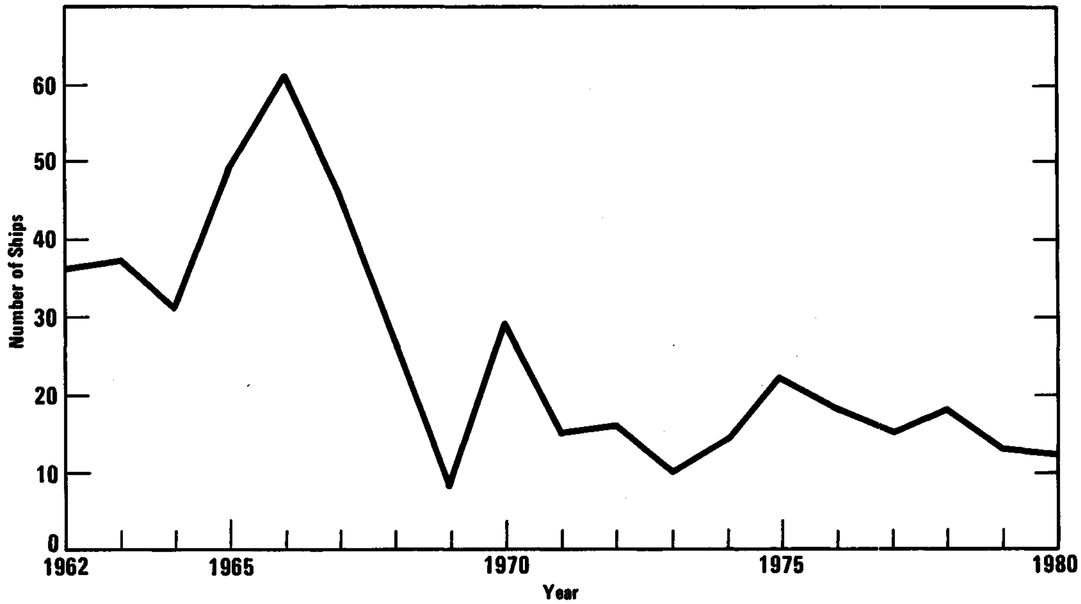
frigates (DLG/DLGN) were reclassified as cruisers (CG/CGN), and the term "frigate" (FF/FFG) was applied to smaller ships that had previously been designated as "ocean escorts" (DE/DEG). In 1979, a new guided missile destroyer class, DDG-47, was administratively designated as a cruiser, CG-47, with the jusification that the cruiser designation was more appropriate to its capabilities.

Figure 2.
Naval Shipbuilding Authorizations, 1962-1980



into the 1980s, new ship authorizations have remained substantially below the levels of the 1960s. In the 1990s, ships built in the high production period of the 1960s will reach 30 years of age and almost certainly will be retired. This will result in a substantial reduction in the size of the U.S. fleet if new ship authorizations continue at the same levels that have prevailed over the past decade. The drop is illustrated for the case of major surface combatants, often called "battle group surface combatants," by Figure 3, which plots force levels to the year 2000 given existing units, presently anticipated retirements, and currently authorized new construction. Approximately 65 surface combatants must be delivered in the 10-year period 1987-1997 just to maintain current force levels. That represents an average of 6.5 new surface combatants per year, significantly higher than the average of 3.3 new cruisers/destroyers authorized each year during the past decade.

Frigates, which are smaller surface combatants not classed by the Navy as battle group units, are intended for use in lower-threat missions. Frigates perform a variety of vital naval

tasks--such as escort of convoys and replenishment ships, and support of amphibious groups--where it is important to have sufficient numbers of ships available. Because of active building programs in the late 1960s and into the 1980s, frigate force levels will remain relatively high with respect to the current level through the 1990s (see Figure 4).

Force Level Objectives

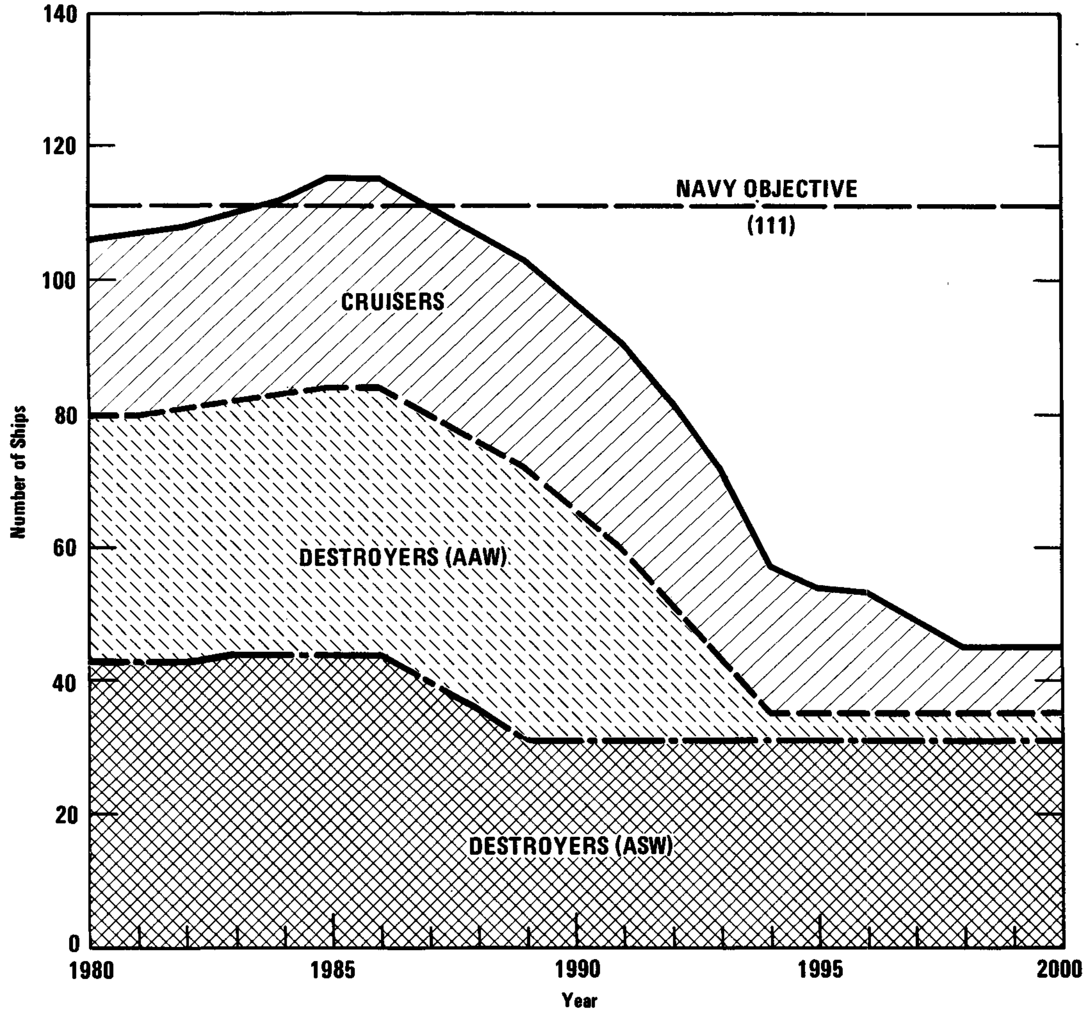
The dashed lines labeled "objective" in Figures 3 and 4 represent Navy force level objectives presented to the Congress in testimony in February 1980. The Navy has been careful to characterize these as only "minimum requirements." In the case of frigates, for example, the Navy stressed that, although anticipated force levels would exceed the stated objective, even more ships of that kind would undoubtedly be needed in a general war. 2/

The force level objectives presented by the Navy suggest that the most acute need for surface combatant units in the 1990s will be for battle group ships (see Figure 3). Although the projected decline from current force levels will not begin until the early 1990s, planning and funding for a program to replace ships scheduled for retirement should begin now, given the long lead time required to design and build modern warships and the combat system components they carry.

The Navy has recently initiated design studies for a new surface combatant, designated "DDGX," whose construction would begin in the mid-1980s. The Navy intends this ship to be a "battle group" combatant with a highly capable anti-air warfare (AAW) system and an antisubmarine warfare (ASW) screening capability using active sonar. Initial Navy plans called for procurement of about 50 of these ships, making the DDGX the major new surface combatant procurement item through the remainder of the century.

2/ Testimony of Vice Admiral James H. Doyle, Deputy Chief of Naval Operations for Surface Warfare, in Military Posture and H.R. 6495, Hearings before the Subcommittee on Seapower and Strategic and Critical Materials, House Committee on Armed Services, 96:2 (February and March 1980), Part 3, p. 91.

Figure 3.
Projected Force Levels for Battle Group Surface Combatants



Note: Includes authorizations through fiscal year 1981. Objective of 111 was specified to the Congress in Navy testimony of February 1980. Testimony given to the Congress in March 1981 suggested a new, higher level of 137.

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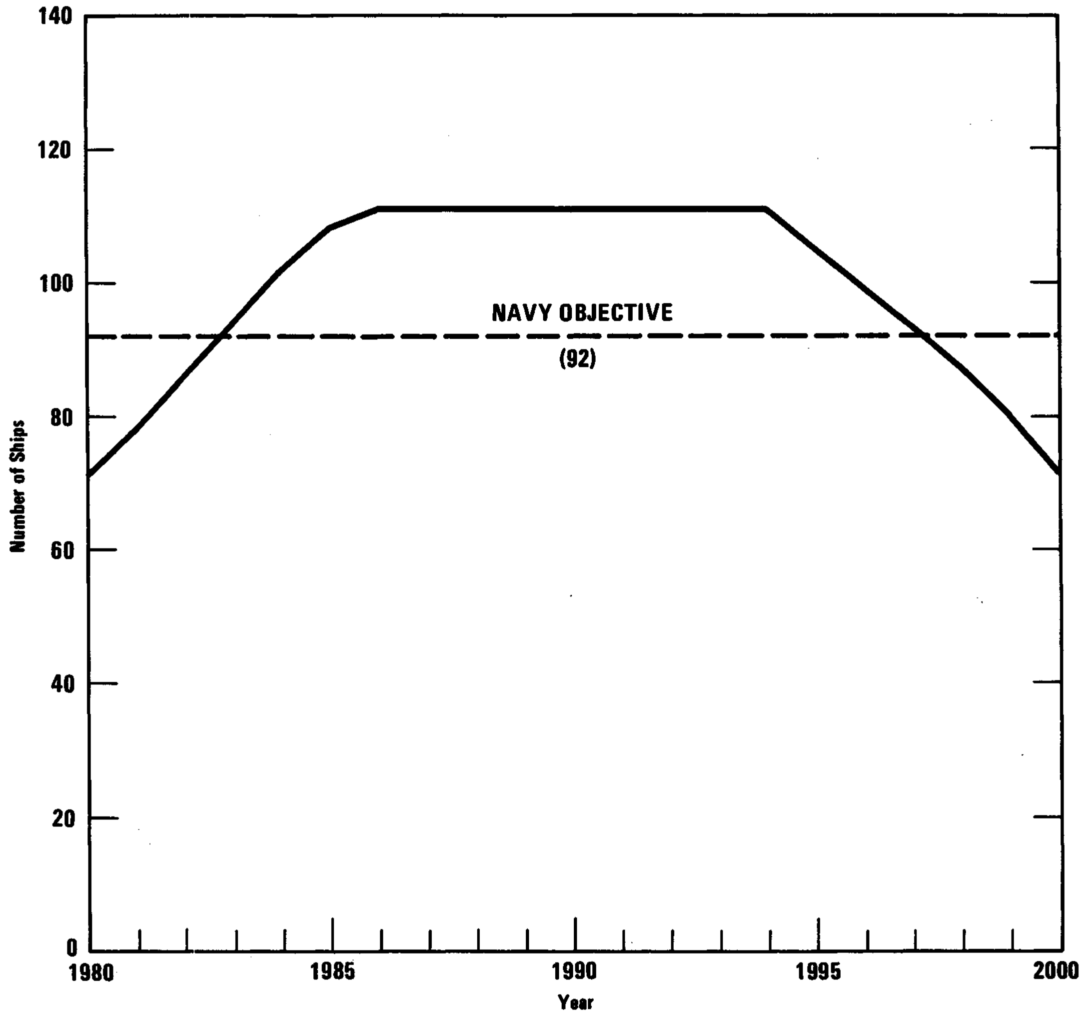
Figure 4.
Projected Force Levels for Frigates



Note: Includes authorizations through fiscal year 1981. Objective of 92 was specified to the Congress in Navy testimony of February 1980. Testimony given to the Congress in March 1981 suggested a new, higher level of 101.

THE NAVY'S PROPOSED SURFACE COMBATANT REQUIREMENTS

The Navy presently intends that its major offensive striking forces in a future war be carrier battle groups. At a procurement cost of more than $16 billion, a carrier battle group represents a very large investment in ship construction. The Navy believes that sufficient forces should be available to maintain at least six carrier battle groups, each containing two aircraft carriers, three CG-47-class AEGIS ships, and nine other surface combatants. Carrier battle group requirements, therefore, generate a need for 72 surface combatants.

The Navy also sees a role for naval combat groups that do not contain carriers. These units, called surface action groups (SAGs), would undertake less demanding missions than carrier battle groups. A typical SAG might be composed of a CG-47-class cruiser and three other surface combatants. The Navy believes sufficient forces should be maintained to support at least three SAGs, which would require a total of 12 surface combatants.

The above offensively oriented groups should, in the Navy's view, be composed of higher-capability battle group surface combatants. For other tasks, the Navy would use the lower-capability frigates as well. Such tasks include support of amphibious operations, which would require 17 surface combatants, and underway replenishment group protection, which would require another 32 units.

Finally, convoy escort requirements must be considered. Force level requirements for this task are highly sensitive to the number of convoys assumed and to the contribution of U.S. allies to the convoy escort forces. Based on its assumptions as to convoy requirements and the level of allied support, the Navy believes that convoy support will require about 70 U.S. surface combatants. 3/

3/ Convoy escort requirements vary considerably depending upon the scenario. A recent CBO study found that escort requirements for the North Atlantic could range between 59 and 273 units, depending upon the assumptions made. Allowing for probable diversion of allied ships to other tasks, U.S. allies could be expected to provide only about 56 convoy escorts, leaving a requirement for as many as 217 escorts to be supplied by the United States or by additional allied

These force requirements for surface combatants are summarized in Table 1.

The force requirement rationale traced above is a commendable attempt by the Navy to construct a logical and coherent basis for force planning from which future shipbuilding requirements can be derived. Like any such plan, it rests upon assumptions about the future whose validity ultimately can be determined only by future events. The Navy does not characterize these as any more than minimum requirements. 4/ Actual conditions in some future war could, of course, generate a requirement for a different kind of Navy in terms of numbers of ships, mix of ships, or both. Chapter IV will examine in more detail how changes in requirements might affect the number and mix of surface combatants desired for the Navy.

QUALITATIVE ASPECTS

The numerical assessments made in the previous section are only one measure of naval strength and should not be considered in isolation from the capabilities of the ships counted. Clearly, not only must there be enough ships, but the ships available must be capable of performing their missions. 5/

Periodic modernization of the combat system capabilities of existing warships is a subject which, although it generally receives less attention than is accorded new construction programs, is of potentially equal or greater importance to overall force

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construction. See Congressional Budget Office, Shaping the General Purpose Navy of the Eighties: Issues for Fiscal Years 1981-1985 (January 1980), pp. 56-58.

4/ One consideration not explicitly included in Table 1 and in the testimony from which it is derived is a factor to account for ship overhauls. Since at any given time some portion (typically about 15 percent) of the Navy's ships is undergoing overhaul, all of the forces in Table 1 would not be available at any one time unless the total fleet was about 15 percent larger than the number shown.

5/ A discussion of current surface combatant ship types and their capabilities is contained in Appendix A.

TABLE 1. BREAKDOWN OF THE NAVY'S SURFACE COMBATANT FORCE LEVEL OBJECTIVE (203 SHIPS)

Mission Requirements	Number of Ships Required					
	CGN	CG-47	DDG X	DD-993	DD-963	FF/FFG
Six Two-Carrier Battle Groups						
3 CG-47s	--	18	--	--	--	--
5 DDG X/CGNs	6	--	24	--	--	--
4 DD-963s	--	--	--	--	24	--
Three Surface Action Groups						
1 CG-47	--	3	--	--	--	--
3 DDG Xs	--	--	9	--	--	--
Amphibious Force a/						
8 DDG Xs	--	--	8	--	--	--
4 DD-993s	--	--	--	4	--	--
5 FFG/FFs	--	--	--	--	--	5
Seven Convoys						
1 DD-963	--	--	--	--	7	--
9 FFG/FFs	--	--	--	--	--	63
Eight Underway Replenishment Groups						
1 DDG X	--	--	8	--	--	--
3 FFG/FFs	--	--	--	--	--	24
Total	6	21	49	4	31	92

SOURCE: Testimony of Vice Admiral James H. Doyle, USN, Deputy Chief of Naval Operations for Surface Warfare, in Military Posture and H.R. 6495, Hearings before the Subcommittee on Seapower and Strategic and Critical Materials, House Committee on Armed Services, 96:2 (February and March 1980), Part 3, pp. 87-88.

a/ Sufficient to support 1.15 Marine Amphibious Force (MAF).

effectiveness. Although the hull and machinery of a ship can usually perform adequately for 30 years, or even longer if necessary, combat system effectiveness typically declines at a much faster pace; a combat system can become outmoded in 10 years or less. If the modernization of older ships is neglected, numerical assessments of naval forces can be misleading. Naval power is a function not only of fleet size but also of the ability of the ships that make up the fleet to perform their missions in a combat environment. New weapons systems can be introduced into the fleet by building new ships, of course, but often fleet capabilities can be upgraded much more rapidly and at lower cost by "backfitting" new weapons systems onto existing ships.

An example of such a modernization program of particular importance to existing cruisers and destroyers is AAW system modernization. The AAW missile systems carried by most current guided missile cruisers and destroyers were designed before the cruise missile became a prime AAW concern and thus are not adequate for the current threat. To address this problem, the Navy has developed several backfit programs to upgrade the capabilities of its older guided missile ships. Three such programs are:

- o CG/SM-2 Upgrade;
- o New Threat Upgrade (NTU); and
- o DDG-2 Class Upgrade.

The CG/SM-2 Upgrade will provide the guided missile ships with a greatly expanded engagement envelope (that is, an increased intercept range and altitude capability) and a fourfold increase in firepower (number of targets engaged per unit of time). The NTU program makes these range and firepower gains sustainable in an electronic countermeasures (ECM) environment. The DDG-2 Upgrade will improve the reliability of the DDG-2-class destroyers. 6/

Given the high cost and resulting slow pace of the CG-47 construction program, these missile ship modernization programs are perhaps the only way to introduce substantial numbers of

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6/ Appendix B provides a more detailed discussion of these three modernization programs.

upgraded AAW systems into the fleet during the the 1980s. The presently deferred CG/SM-2 Upgrade for the DDG-37 class alone would put 10 ships at sea with a modern, extended-range AAW capability at less than one-tenth the cost of a single CG-47.

RECAPITULATION: IMPENDING BLOCK OBSOLESCENCE FOR BATTLE GROUP SURFACE COMBATANTS IN THE 1990s

The picture that emerges from the above discussion is one of a Navy diminished in size from its former levels but now stabilizing at a level of just under 550 ships. The age of the ships presently in the fleet, however, portends another sharp drop in force level in the 1990s unless future ship procurement rates are increased from those prevailing over the past decade.

Existing surface combatant force levels are presently near the Navy's minimum objectives. Frigate force levels will continue to rise over the next few years as new ships now authorized for construction enter the fleet. Cruiser/destroyer, or "battle group," force levels are rising much more slowly, however, and will fall off abruptly in the 1990s. Compounding this is the fact that ships scheduled for retirement in the 1990s are now entering their third decade of service and in many cases already have obsolescent combat capabilities.

The question that arises is what, if anything, should be done about this? Will surface combatants continue to serve a useful function in modern warfare? Is that function sufficiently important to justify the substantial investment that will be required to replace aging units? This issue will be addressed in the next chapter.

CHAPTER III. ROLE OF THE SURFACE COMBATANT IN NAVAL WARFARE: RENAISSANCE THROUGH TECHNOLOGY

Surface combatants, perhaps more than any other active naval weapons system, form a link with the Navy's past. Unlike aircraft carriers and submarines, which are quintessentially 20th century creations, surface combatants are the direct descendants of an unbroken line of fighting ships stretching back in time to the earliest sea battles. As such, they are the inheritors not only of centuries of naval tradition but also of centuries of evolutionary development in warship design. A question for current naval planners, and for the Congress, is whether they are more than this. Are present-day surface combatants merely the vestigial remnant of a long tradition, or are they still a vital component of naval forces whose place remains secure in logic as well as in tradition?

SURFACE COMBATANTS IN THE 20TH CENTURY: GRANDEUR AND DECLINE

Until World War II, the surface combatant was the centerpiece of naval forces. Dramatic improvements were made in the late 19th century, when the sail-driven wooden ships that had existed for centuries were replaced by new steam-propelled steel warships mounting large rifled guns. Those steel ships evolved into a variety of forms, dominated by huge, heavily armored battleships that carried enormous guns capable of delivering several tons of armor-piercing shells in a single broadside on a target 20 miles away. This era also saw the development of the big-gun cruisers, which were somewhat smaller, less heavily armored, and carried smaller guns than battleships but were still possessed of formidable firepower. At the low end of the spectrum was the destroyer, small and fast, carrying little or no armor, and armed with torpedoes and relatively small guns. These ships could operate in company to form a battle fleet, or in smaller groups or independently for patrol and presence missions. In their heyday, they were the essence of naval power.

Early in the 20th century, as the surface combatants were reaching the peak of their power and majesty, the Navy began to experiment with two new vehicles, the airplane and the submarine.

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By the eve of World War II, aircraft and submarines had become firmly established in the spectrum of naval weapons; by the end of that war, both had decisively proven their capabilities, and the aircraft carrier and the submarine displaced surface combatants at center stage in the fleet.

The years following World War II saw continued dramatic improvements in naval forces. Jet-propelled aircraft, much faster and more powerful than earlier types, were introduced into the fleet, and new and larger aircraft carriers were built to accommodate them. The development of nuclear propulsion greatly expanded the horizons for submarine performance, significantly strengthening the submarine's already strong claim to prominence.

In the meantime, the surface combatant force was adjusting to a new role. The mighty battleships and cruisers were decommissioned rapidly in the years following World War II. No longer the centerpiece of the battle fleet, the surface combatant assumed primarily an escort role--that is, protecting other ships from attack by aircraft, submarines, or surface ships. This role was most closely associated with the traditional functions of destroyers; consequently, surface combatant construction in the postwar period has been devoted almost exclusively to ships that are derivatives of the destroyer type. 1/ These were built in large, medium, and small variants, designated destroyer leaders (DL), destroyers (DD), and destroyer escorts (DE), respectively. Those designations have since been changed to cruiser, destroyer, and frigate, but all are designed and equipped primarily to perform the escort mission. The aircraft is the offensive strike arm of today's naval fleet; the aircraft carrier is the centerpiece of the U.S. battle group. Surface combatants protect and support the aircraft carriers.

EMERGING TECHNOLOGIES FOR SURFACE COMBATANTS

Recent technological developments hold out the prospect of substantially improved combat capabilities for surface combatants

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1/ The only postwar new-construction ship of the cruiser type--in the sense of a World War II cruiser--was the USS Long Beach (CGN-9), the first nuclear-powered surface warship, commissioned in 1961.

--capabilities that not only will make them better escorts but may also restore some degree of independent strike capability to surface forces. Cruise missiles, autonomous aviation capability, and substantial technical improvements in radar, sonar, and command and control systems are among the factors combining synergistically to improve the combat potential of modern surface warships. Although these same factors are being employed by potential enemies to upgrade their naval forces, vigorous exploitation of new technological opportunities for surface combatants can be expected to produce a net gain in future U.S. naval capabilities.

Engagement Range and Firepower: Key Warship Capabilities

New technological developments that increase a warship's engagement range and firepower can have a particularly dramatic effect upon its combat capabilities. Engagement range and firepower, which are perhaps the most important among the many factors that collectively determine a warship's capabilities, are largely determined by the weapons and sensors mounted on a ship. 2/

Engagement range, the distance at which a ship can first bring enemy units under fire, has long been a key factor in naval warfare. It was, in fact, the basis for the dominance of big-gun ships in the battleship era. Not only did larger guns fire larger

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2/ Endurance and resilience, primarily features of a ship's hull and machinery as opposed to combat system qualities, are two other important determinants of warship capability. Endurance and resilience are properly accorded great importance by U.S. warship designers. Endurance, which is a function both of the distance a ship can travel without refueling and of its ammunition and stores capacity, is clearly important to an oceangoing navy with worldwide deployments. Nuclear power provides the ultimate in endurance, but at substantial expense. Resilience, or the ability of a ship to survive the effects of combat, is also an important indicator of warship capability. Resilience is the product of many factors, such as system redundancy and shock hardening, as well as of a myriad of construction details that have been found by experience to make a ship resistant to damage. Collectively, all of these items make warship construction more costly, in general, than commercial ship construction.

shells, but they also had longer range. The battleship, therefore, with its larger guns, could destroy a cruiser before the cruiser could even close to engagement range; a cruiser could similarly outrange a destroyer. Aircraft, however, outranged all of the big guns and, as a consequence, the aircraft carrier became dominant at sea.

How New Weapons Increase Engagement Range. Deployment of newly developed cruise missiles in the surface combatant force could yield significant increases in engagement range. The cruise missile is basically a pilotless airplane that carries an explosive charge and utilizes a homing device to guide it to its target; hence it performs the function of an attacking airplane, although with far less tactical flexibility than a manned aircraft. Successful engagement of a target, of course, depends on much more than just the distance a missile will fly or a shell can be fired. A successful engagement requires the ability to detect a target initially, classify it as enemy or not, track it with sufficient accuracy for weapon launch and delivery, and control and coordinate the entire process. To the extent that surface combatants, either individually or in company with supporting units, can perform these additional targeting functions, cruise missiles can provide them with unprecedented new long-range attack capabilities against targets both at sea and ashore.

Firepower: Key to AAW and Antiship Missile Defense. Firepower is the level of fire a ship can maintain and, more importantly in many situations, the number of targets it can engage simultaneously. In the sailing-ship era, firepower was the chief determinant of warship strength--that is, the number of guns mounted on a ship provided a good index of its capability in battle. While today's combat environment is much more complex, the underlying principle has not changed. A ship that can sustain a high volume of fire against enemy forces enjoys an important advantage.

Of particular significance in the present combat environment is the ability to engage multiple targets simultaneously. Indeed, modern weapons and command and control capabilities could make it possible to orchestrate coordinated attacks so as to overwhelm a ship's defenses with multiple weapons all arriving nearly simultaneously. Observation of Soviet fleet exercises clearly points to this as a likely Soviet tactic. Such attacks become more difficult to accomplish successfully as the firepower and saturation threshold of the target ships (or aggregates

of ships) is raised. Consequently, firepower has particular relevance to naval anti-air warfare systems because of the threat posed by cruise missiles. Whether launched from an airplane, surface ship, or submarine, a cruise missile in flight is an AAW problem.

Deployment of Cruise Missiles: New Naval Strike Weapon

The cruise missile, a promising new offensive weapon for surface combatants, also poses a serious new threat to them. In a contest at sea, the key factor will probably be engagement range. The side that, through a combination of tactics, surveillance, and weapons capabilities, attacks first will enjoy an important advantage. High firepower, particularly in AAW, might, however, enable the opposing force to overcome the attacker's advantage.

Cruise missiles were first developed as tactical naval weapons in the Soviet Union about 20 years ago; the United States initiated its own development programs about 10 years later. 3/ The Soviets were motivated to develop cruise missiles as an alternative, and an antidote, to the overwhelming U.S. advantage in carrier-based tactical air power. Confident in its tactical air power advantage, the United States was relatively late in taking up cruise missile development but has placed increasing emphasis on cruise missile systems in the past decade. Among the various types that have been developed, two--the Harpoon (AGM/RGM-84) and the Tomahawk (BGM-109)--are of particular interest for surface combatant applications. 4/

3/ The United States had developed operational cruise missiles for strategic missions at an earlier date. Regulus cruise missiles were deployed in submarines before Polaris ballistic missiles were developed.

4/ In addition to the United States and the Soviet Union, six other nations, all U.S. allies, have developed cruise missile designs of their own, and cruise missiles are now employed by navies all over the world. The Soviets have provided cruise missiles to many of their client states; the Soviet (SS-N-2) Styx missile is now employed in the navies of 21 different nations. The U.S. Harpoon will be employed by at least nine nations.

One of the chief attractions of the cruise missile is its compatibility with a variety of launch vehicles. 5/ The Harpoon, although initially designed as an air-launched cruise missile, is now launched from surface ships and submarines as well. For launches from surface ships, it can utilize existing Tartar, Terrier, Standard, or ASROC (antisubmarine rocket) missile launchers, thus saving expensive backfit costs. Alternatively, it can be launched from relatively simple "box" launchers fixed to a ship's deck. For launches from submarines, the missile must be placed in a buoyant launch capsule that can be fitted into standard submarine torpedo tubes.

Harpoon. Developed and deployed as an antiship weapon, Harpoon uses inertial guidance during its cruise phase and an active radar seeker for terminal homing. 6/ It has a range of 120 nautical miles when launched from aircraft and about 60 nautical miles when launched from surface ships or submarines.

Tomahawk. A somewhat newer and more capable missile than Harpoon, Tomahawk also can be launched from aircraft, surface ships, or submarines, and is slated to have a ground-launched version as well. Tomahawk will be deployed in a long-range (1,550 nautical miles) land-attack version called the Tactical Land Attack Missile (TLAM) and a shorter-range (280 nautical miles) antiship version called the Tactical Antiship Missile (TASM). Capable of carrying either a nuclear or a conventional warhead,

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5/ U.S. cruise missiles (and missiles developed by U.S. allies) tend to be much smaller than Soviet versions. Although larger cruise missiles can obviously carry larger warheads, the smaller size of U.S. missiles allows more of them to be carried on a launch vehicle and permits much more flexibility in selecting and outfitting launch vehicles.

6/ Terminal homing devices, which enable a missile to "see" and home on its target, can take a variety of forms. These include active radar (a small radar set carried in the missile), a missile-borne television camera, or a seeker that homes on infrared or radio frequency energy eminating from the target. Each of these has its advantages and disadvantages, but active radar is the most common type of terminal guidance ("seeker") for antiship cruise missiles.

the land-attack version will use terrain comparison (TERCOM) guidance to navigate to its target.

The TERCOM system uses a radar altimeter to scan the terrain below at predetermined intervals during the missile's flight. The system compares the topography seen from the missile to a reference ground profile programmed into its memory. The movement required to effect a match yields coordinates that are used to update the missile's position reference. If such a "fix" can be taken just before impact, very precise guidance is obtained. The antiship version of Tomahawk uses a modified version of the Harpoon active radar seeker for terminal homing. Tomahawk has been designed to have a very small radar cross-section and a small infrared signature that should make it very difficult to destroy despite its subsonic speed. Initial operational capability (IOC) for the Tomahawk is scheduled in fiscal year 1982 for the submarine fleet and in fiscal year 1983 for the surface combatant force.

Over-the-Horizon Surveillance and Targeting: Essential for Cruise Missiles and Tactical Success at Sea

Although one of the most important benefits of cruise missiles is the increase in engagement range they provide, this benefit is not necessarily realized simply by equipping a ship with cruise missile launchers. Because the curvature of the earth limits a ship from detecting other ships, either visually or by radar, at distances beyond 25 to 30 nautical miles, a cruise-missile-equipped ship may be unable to exploit the full range of a missile such as Harpoon (to say nothing of the 280-nautical-mile range of Tomahawk). This over-the-horizon (OTH) detection and targeting problem is the most important issue in realizing the full potential of the cruise missile weapon at sea. To obtain over-the-horizon targeting information, a ship must rely on data from other sources that can detect and target distant enemy units. These can include the ship's own aircraft, such as LAMPS (Light Airborne Multipurpose System) helicopters; other ship-based or land-based aircraft in the area; or a variety of other external sources such as satellites or intelligence. 7/

7/ Aircraft are particularly attractive for the OTH surveillance and targeting role because their speed and elevation enable them to search very large areas in a short time. LAMPS has

The Navy intends to use OTH targeting information from any one or several of these sources and is experimenting with ways of efficiently correlating and displaying the information available for antisurface warfare (ASuW). 8/

The over-the-horizon targeting problem for cruise missiles is a specific case of the broader and historically long-standing problem of obtaining information on the location and movements of enemy forces at sea. Superiority over the enemy in this area can yield decisive benefits; conversely, enemy superiority, even if in this area alone, can have disastrous effects. No matter how effective naval weapons may be, they cannot be employed without knowledge of the enemy's location; likewise, no matter how crude the enemy's weapons may be, he can win if he attacks first.

The over-the-horizon targeting problem is, therefore, both a manifestation and a subset of a very fundamental problem in naval warfare. It is likely that the side that best solves the targeting problem for cruise missiles will not only realize an advantage in their employment, but will also enjoy a more basic advantage in tactical information at sea. The Soviets seem to be well aware of this and have developed a large, highly centralized system to

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the advantage of being indigenous to the ship's combat system, although other aircraft, such as land-based P-3Cs, may carry better sensors. Radar satellites, when and if deployed, could surveil the oceans more rapidly still, but would provide massive amounts of data to be correlated and would probably be less able than aircraft to provide classification and other essential information to the missile ship.

8/ Under the OUTLAW SHARK program, the Navy has developed a device, AN/USQ-81(V), to collect and display targeting data. Capabilities developed under this program will be incorporated in the Common Weapons Control System (CWCS) that is being developed for the Tomahawk. The first prototype CWCS is scheduled to go to sea in late fiscal year 1981, and is expected to be ready for fleet introduction on a schedule consistent with the fiscal year 1983 Tomahawk IOC date for surface combatants. Testimony of Honorable David E. Mann, Assistant Secretary of the Navy for Research, Engineering, and Systems, in Department of Defense Appropriations, Fiscal Year 1981, Hearings before the Subcommittee on Defense, Senate Committee on Appropriations, 96:2 (1980), Part 4, pp. 127-29.

collect information on U.S. forces and to direct and coordinate attacks against them. 9/ The United States enjoys an advantage in some aspects of this contest, particularly its superiority in electronics and data-processing technology and in carrier-based tactical air power. It is not clear, however, that U.S. efforts in surveillance and targeting are as well focused or as effective as Soviet efforts in this area.

Helicopters: Over-the-Horizon Surveillance Today. Perhaps the most significant development in extending surface combatant surveillance and targeting capability in the past decade has been the rapid proliferation of helicopter landing and support facilities on naval ships. Helicopters have now become a common feature on most new surface combatant designs, even on relatively small frigates. This trend has been particularly evident in the United States, and almost all of the recently designed surface combatants--CGN-38-class cruisers, DD-963 and DD-993-class destroyers, FFG-7-class frigates, and CG-47-class cruisers--have been equipped with helicopter support facilities. This movement toward an aircraft-support capability has been motivated largely by a need to expand the reach of the surface warship--that is, to expand the area over which it can detect and prosecute targets.

Vertical/Short Takeoff and Landing (V/STOL) Aircraft: Over-the-Horizon Surveillance for Tomorrow? The currently emerging V/STOL technology is particularly promising for over-the-horizon surveillance and attack. The helicopters now widely used by modern surface combatants are the best aircraft presently available for operations from small, noncarrier platforms. As a general rule, however, helicopters compare unfavorably with fixed-wing aircraft in terms of speed, range, and endurance. V/STOL technology offers the possibility of obtaining flight performance more nearly comparable to that of fixed-wing aircraft with an airplane that can land and take off from small platforms. Examples of V/STOL airplanes for the fleet air coverage mission that offer much better speed and endurance than helicopters are the Bell XV-15 tilt-rotor aircraft and the Grumman turbofan V/STOL-design 698. Aircraft of this type, if and when they become available, could provide substantially improved performance, as shown in Table 2, over that available from helicopters. At

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9/ For a discussion of the Soviet approach, see William J. Ruhe, "1980 Soviet Strategy for War at Sea," Defense Electronics (July 1980), pp. 43-51.

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TABLE 2. COMPARISON OF HELICOPTER AND V/STOL CAPABILITIES

	Helicopter (UTTAS/LAMPS III)	V/STOL (Grumman 698)
Performance		
Maximum speed (knots)	160	500
Ceiling (thousand feet)	19	50
Radius (nautical miles)	160	700
Time on station at 100 nautical miles (hours)	2.0	3.6
Systems Compatibility		
Airborne early warning radar installation	No	Yes
Armament	Fair	Better
Ship Compatibility		
Deck area requirement	Medium	Smaller
Folding complexity	Complex	Simpler
Gust susceptibility	High	Lower
Development Status	Demonstrated	Undemonstrated

SOURCES: Jane's All the World's Aircraft, 1980-81; Robert W. Kress, "Surface Combatant Fleet Offensive/Defensive Enhancement by High Performance Turbofan VTOL Aircraft" (paper prepared for delivery at the August 1980 AIAA Aircraft Systems Meeting; processed).

the very least, they could provide the fleet with a means of more fully utilizing the long-range weapons now becoming available. 10/

10/ Moreover, V/STOL aircraft can provide naval forces with a more widely distributed and more flexibly based aviation capability than is possible with large aircraft carriers alone. Some knowledgeable observers believe that such

Towed Arrays: A New Kind of Sonar That May Produce the Longer-Range Submarine Kills Needed Against Today's Threat

The long-range weapons now available to submarines have made it essential for ASW escorts to be able to engage attacking submarines at much longer ranges than was previously the case.

Today's submarines are armed with long-range cruise missiles and modern, wire-guided torpedoes whose accoustic homing devices permit them to be fired from ranges as great as 10 nautical miles or more, with reasonable chance of success. This is considerably beyond the engagement range of even relatively recent ASW ships that use hull-mounted active sonar and hull-borne ASW weapons such as ASROC. 11/

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distributed basing is essential for naval forces in the current tactical environment. See, for example, Admiral Stansfield Turner, USN (Ret.), "Thinking About the Future of the Navy," U.S. Naval Institute Proceedings (August 1980), pp. 66-69. The Defense Science Board Task Force on Surface Ship Vulnerability took the view in a recent study that the Navy should reduce dependence on "citadels" and distribute modern offensive and defensive capabilities among ships other than aircraft carriers and CG-47s. For an unclassified version of that report, see Military Posture and H.R. 6495, Hearings before the Subcommittee on Seapower and Strategic and Critical Materials, House Committee on Armed Services, 96:2 (February and March 1980), Part 4, Book 1, pp. 1112-23. Another means of distributing aviation capability that could provide excellent flexibility is the ARAPAHO concept. ARAPAHO is a set of modular, containerized aircraft support facilities together with modular living facilities that can be rapidly erected on any of a wide variety of merchant ships. For a recent discussion of the ARAPAHO program, see James J. Mulquin, "Navy Completes First Flight Tests on ARAPAHO," Seapower (November 1980), p. 31; and James J. Mulquin, "Wartime Commercial Ship Protection with ARAPAHO," British Aerospace Inc. Quarterly (November 1980), p. 16.

11/ Active sonar systems put a pulse of accoustic energy (a "ping") into the water and listen for echoes off the submarine hull. Passive sonar systems listen for noises emanating from the submarine. ASROC uses a rocket to propel an ASW torpedo to the immediate vicinity of a submarine contact.

The Navy has undertaken several programs to improve the ASW engagement range of surface combatants. One such initiative is the development of tactical towed-array sonar systems (TACTAS), which are passive sonar systems that can provide much longer-range detection of submarines than is normally possible with active sonars. 12/ Another such development is the LAMPS helicopter, which is used to investigate and prosecute ASW contacts detected by a ship's sonar systems. (This function is in addition to the over-the-horizon surveillance and targeting function discussed above.) Towed-array sonar systems consist of a long linear array of hydrophones towed well behind a ship by a wire, together with sophisticated electronic equipment aboard the ship for analyzing the signal from the hydrophones. They offer the surface ship, for the first time, the possibility of achieving parity with the submarine in passive listening capability. The long-range detections made possible by towed-array sonar systems will be of limited value, however, without a means of localizing and attacking enemy submarines--the function performed by LAMPS. LAMPS and/or other ASW aircraft in the vicinity of the towed-array ship can extend the surface combatant's ASW engagement range to something more commensurate with that of modern submarine weapons. The Navy is also developing an integrated ASW network that will correlate and transmit information derived from various sources--intelligence, satellites, SOSUS, SURTASS, and tactical aircraft--to forces at sea. 13/ These developments establish some basis for optimism that the Navy will achieve the means to engage submarines successfully beyond the immediate proximity of a circular screen.

Anti-Air Warfare: Increased Threat, Increased Capabilities

Aircraft and cruise missiles pose a major threat to surface combatants, and, in order to survive in the modern combat

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12/ Two types of tactical towed-array sonar systems are currently under development by the Navy. These are the AN/SQR-18 for the FF-1052-class frigates and the AN/SQR-19 currently scheduled to be deployed aboard the DD-963 and CG-47-class ships.

13/ SOSUS (Sound Surveillance System) is a system of large fixed sea-bottom hydrophone arrays that passively listen for sounds generated by submarines. SURTASS (Surveillance Towed-Array Sonar System) is a group of towed arrays deployed on ships (T-AGOS) that will supplement SOSUS and allow increased surveillance in areas of particular interest.

environment, ships must be able to defend themselves against both. Only if it can survive against enemy attack can a warship continue its offensive functions of engaging enemy warships and shore installations.

A steady increase in military aircraft performance over the years has demanded a parallel increase in the capabilities of AAW systems. This led to the introduction in the 1950s of complex, expensive AAW missile systems for surface warships. As the performance of potential targets have grown, the performance demands on modern AAW systems have become very high indeed. For the past decade, naval surface AAW development has been driven primarily by the Soviet cruise missile threat.

Cruise missiles are difficult AAW targets. They fly very fast (as much as several times the speed of sound) and approach their target in ways that are intended to maximize the difficulty of countering them with AAW. For example, "sea-skimmer" versions fly just over the water and cannot be detected by shipboard radars until they are less than two minutes from impact. Cruise missiles may also be programmed to approach at a very high altitude and dive steeply at their target. There are many variations between those extremes. The defense problem is compounded in a coordinated attack by several missiles arriving at their target simultaneously. Since the relatively large size of Soviet cruise missiles limits the number that can be carried by a single ship, submarine, or airplane, a high-saturation attack requires a large aggregation of forces such as might be organized most readily in waters near to Soviet operating bases.

The development of U.S. naval AAW systems in the past decade has proceeded in two general areas in response to the growing cruise missile threat: point defense systems and area systems. The relatively short-range point defense AAW systems are intended to defeat missiles or aircraft approaching the ship on which the system is mounted. Systems of this kind include the NATO Seasparrow and the Phalanx Close-In Weapon System (CIWS) now being deployed in the U.S. fleet. Area systems, on the other hand, are longer-range systems that can extend protection to other ships in the vicinity as well as to the missile ship itself. Included in this category are the older Terrier and Tartar systems, the MK92 system on FFG-7 frigates, and the AEGIS system planned for deployment on the new CG-47-class cruisers. With Seasparrow and Phalanx now being deployed and in production, improvements in area systems currently have priority in AAW system development.

Area AAW improvements include backfit programs (such as the DDG Upgrade and New Threat Upgrade programs mentioned in Chapter II) as well as development of the AEGIS system. AEGIS is by far the most powerful, and most expensive, AAW system ever developed for shipboard use. The system is built around a large phased-array radar system 14/ that can automatically track many targets simultaneously. Using the new, longer-range Standard (SM-2) missile, AEGIS can engage targets at longer range than is possible with the presently deployed Standard (SM-1) missile. Perhaps the biggest improvement in performance offered by AEGIS, however, is in firepower. The automatic multiple-target-tracking capability of its AN/SPY-1 radar, together with other features of the system, will permit AEGIS to deal with a much greater number of AAW targets than was possible with earlier systems. AEGIS is, therefore, particularly well equipped to counter the sort of coordinated cruise missile saturation attack discussed above. Its capabilities do not come cheaply, however. The CG-47-class ships will cost $1.02 billion each. AEGIS is another substantial step in the continuing upgrade of threat and response in AAW.

Modern AAW Missile Systems: Products of an Evolutionary Development

In order to understand the current state of the art in AAW systems as well as future development alternatives, it may be useful to review a little of the technical background of these systems. Surface AAW missile systems have undergone a substantial technical evolution over the past 25 years. The early systems, such as Terrier, were beam-rider missiles that simply "rode out" a beam of electromagnetic energy until they intercepted their target. The major disadvantage of these systems was that the guidance beam tended to diverge and weaken with increasing range, whereas precisely the opposite effect was needed as the missile approached its target. To overcome this problem, semi-active guidance was developed in the late 1950s. In the newer semi-active guidance systems, such as the MK92 system currently used

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14/ A phased-array radar is one in which the antenna faces are physically fixed, rather than being mechanically rotated, and the radar is scanned electronically in azimuth and elevation by sequential phasing of the many elements in its antenna system.

on FFG-7-class frigates, the target is "illuminated" by an electromagnetic beam from the ship's fire control radar, and the missile homes on the energy reflected from the target rather than simply riding out a diverging guidance beam from the ship.

A drawback of this system is its tendency to become saturated during high-density attacks, since an illuminating radar must be devoted exclusively to a single target until that target has been destroyed. One way to overcome this difficulty is to use intermittent semi-active illumination in combination with a "track-while-scan" (TWS) weapon control system (WCS). Another technique uses a WCS-to-missile command link to provide the missile with midcourse guidance commands. With these two midcourse guidance techniques, guidance is not continuous, and several targets may be tracked and illuminated by the same radar. Only in the final phase of interception is continuous, precise guidance necessary. This represents, however, a significant jump in technological sophistication, involving the use of high-speed computers.

The AEGIS system incorporates the features of the latter type described above, using TWS and command midcourse guidance. As configured for the CG-47-class ships, the system will have four illuminators, and therefore will be able to engage at least four targets simultaneously. Since the SM-2 missile requires continuous illumination only during the final phase of its flight, the AEGIS system, with its automatic tracking capability, will be able to control more than four missiles simultaneously for long-range engagements.

New Technologies for AAW Missile Systems: More Firepower for Tomorrow's Warships

Newly emerging technology may provide still further improvements in firepower. New technologies of particular promise are interrupted continuous-wave illumination (ICW) and agile beam fire control radars. 15/

15/ Several concepts for advanced fire control radars could provide the basic capabilities discussed here. These include such specific types as the Flexible Adaptive Radar (FLEXAR) and the Terminal Engagement Radar (TER). As used in this report, "Agile Beam Fire Control Radar" is a generic term encompassing a variety of such specific types.

ICW. This technique permits a single fire control radar to control two or more missiles simultaneously in the final phase of their flight. Engineers now believe it may not be necessary for semi-active AAW missiles to receive continuous terminal illumination. Just as a motion picture is composed of a series of discrete still pictures, a series of discrete illumination pulses could be rapidly switched among multiple targets, providing the necessary homing energy to guide several AAW missiles to their individual targets. If, in fact, interception can be achieved with illumination for less than 50 percent of the time during terminal guidance, then two targets might be engaged simultaneously with a single fire control radar. If that requirement could be reduced still further to less than 25 percent, then four targets could be engaged, etc., thus multiplying firepower. The more advanced techniques in this area, which could provide very high firepower, are sometimes called pulsed continuous wave (PCW) illumination.

Agile Beam Fire Control Radar. An agile beam radar could provide the multiple-target track and illumination capability that would be needed with ICW missiles discussed above. 16/ This concept would apply modern electronic scan (versus older mechanical scan) technology to AAW fire control radars. The fire control radars that are now used as illuminators with missile systems, including AEGIS, employ a large mechanical antenna to generate a simple "pencil beam" of electromagnetic energy that illuminates a single target. The large antenna that forms this narrow beam must be precisely stabilized to compensate for both the ship's and the target's motion. Because of its large inertia, the mechanical antenna cannot be used as an ICW multiple-target illuminator.

16/ This could be accomplished either by moving a single beam among multiple targets or by splitting the radar energy into several beams as range decreases. At maximum range, a fire control radar would need maximum power and aperture (a function of antenna size) applied to a single beam of energy to obtain maximum missile performance. At 70 percent of that range, however, the same performance (signal-to-noise ratio) could be obtained with half the power. An agile beam fire control radar would allow the weapon control system to allocate the energy initially directed at one target to two or more targets as range decreased. The tactical advantage of this capability is the flexibility to trade range for firepower as the battle space decreases.

A long-standing problem in (non-AEGIS) AAW missile systems has been difficulty in "handing off" a target from the search radar to the fire control radar. This handoff must be made before the system can engage the target, and it requires the weapon control system to tell the fire control radar precisely where to look to find the target. The handoff problem occurs when the fire control radar does not acquire the target because the search radar's target position information is not accurate enough to get the target in the narrow tracking beam of the fire control, or "illuminating," radar. An agile beam fire control radar could rapidly scan around even a coarsely designated target, and therefore greatly expedite target acquisition and lock-on.

Agile beam technology may well be the next step in improving AAW firepower. Its capabilities become particularly interesting in a jamming environment (or with low-altitude "sea-skimmer" missiles), in which targets may not be detected until the missiles are very close to impact. In such situations, high firepower against short-range targets is vital.

"Front-End" and "Back-End": Two Ways to Upgrade AAW Systems

Agile beam fire control radar technology also impinges upon the issue of whether to emphasize "front-end" or "back-end"--that is, search radar or fire control radar--improvements to AAW systems. AEGIS, to date, has emphasized the search radar end of the system. This approach puts the new-technology emphasis into that part of the system that detects, tracks, and sorts out targets for possible attack.

Another approach, however, would be to put the technology emphasis on the fire control end and develop a system that could quickly lock on and engage targets initially detected by a less sophisticated sensor than the AN/SPY-1. While the approach taken by AEGIS is perhaps the logical one for maximizing effectiveness (since a target cannot be engaged until it has been detected), emphasizing fire control radar improvements would probably be much less expensive (the radar's size and power are much less) and could provide dramatic firepower improvements. These approaches are not mutually exclusive, and both would contribute to system effectiveness.

The technical factors above are pertinent both to improvement programs for existing AAW systems and to development programs for new systems. Present plans call for the AAW system on the new

DDGX to include the Multi-Function Array Radar (MFAR) system, similar in function to the AN/SPY-1 AEGIS radar. A final decision on the AAW fire control system for the DDGX has not yet been made, but it could include an agile beam radar and ICW if the technology is available.

"Back-End" Improvements: Prospective Low Cost and Weight and Easier Backfit

A new AAW fire control system with agile beam illumination/ ICW technology could also be used to upgrade the capability of currently operational surface combatants. Such a system would be particularly attractive if it permitted the ships to use the new Standard (SM-2) missile (which would give them the advantage of the missile's longer range and higher firepower), if it also permitted them to use the Standard (SM-1) missile (so that the considerable existing inventory of these missiles could continue to be used), and if the system was relatively small and modest in power demand (so that the ship impact and installation cost of the system in backfit would be modest). All of these factors militate toward a change in the "back end," or fire control radar, for backfit AAW improvements.

Although the introduction of the AEGIS system in the surface combatant fleet will usher in new capabilities more commensurate with the cruise missile threat, the high cost of AEGIS ships will probably limit their procurement. Also needed, therefore, are improved AAW systems that are smaller and less costly and that can be more widely distributed in the fleet. Fortunately, the newly emerging technologies discussed here show promise of providing such improvement for a wider spectrum of ships. This could result in a dramatic increase in AAW firepower in the 1990s.

Electronic Countermeasures: Major Factor and Major Uncertainty

AAW is also significantly affected by electronic countermeasures (ECM). ECM involves the employment of electronic devices such as jammers to interfere with an enemy's radar, communications, or other electronic systems. ECM can be very effective in degrading the performance of sophisticated, electronically based systems such as those used in AAW. Because of this, special features are often incorporated to make such systems resistant to ECM. Such features, known collectively as ECCM (for electronic counter-countermeasures), may be effective against some ECM

techniques but not against others. The key feature of the technically esoteric subject of ECM/ECCM is that it is highly fluid. A system that is highly resistant to countermeasures today may be severely degraded by some new ECM technique tomorrow, and a new technical or tactical ECCM innovation may restore its effectiveness on the next day. ECM is a significant factor, and a major uncertainty, in assessing the effectiveness of AAW systems and will remain so for the forseeable future. 17/

SURFACE COMBATANTS IN THE 1990s

The trends in naval warfare and the technological developments discussed above appear, on balance, to paint an optimistic picture for surface combatants in the years ahead. Cruise missiles now give surface combatants a long-range strike capability against both ship and land targets. Helicopters, which can provide the long-range surveillance and targeting capabilities required by these weapons, are now being deployed on U.S. surface combatants, and V/STOL aircraft with even greater capability may be available in the future. New towed-array sonar systems now becoming available should extend this partnership between ship and aircraft to ASW as well, and will greatly extend surface combatant engagement range against submarines. New technologies in AAW systems offer the prospect of vastly improved capabilities in the immediate future. Thus, the surface combatant stands to gain substantially in its ability to deal with other

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17/ ECM threats of particular importance to surface combatant AAW systems are jammers that interfere with AAW radars in a manner similar to static on radio. These can be airborne stand-off jammers or jammers accompanying the attacking airplanes. In either case, their effect is to reduce the engagement range of the AAW system or, in the extreme, to defeat its effectiveness altogether. Several approaches may be taken to reduce the effectiveness of jammers. These include using very high power to overwhelm the jammer effects, using sophisticated signal processing to improve the signal-to-noise ratio over the jammer, using a variety of frequencies to force the enemy to spread his jammer power over a wider frequency band, and attempting to destroy the jammer using such things as home-on-jam missiles. All of these approaches, and others as well, will be used in the continuing technical parry and riposte of electronic warfare.

surface ships, submarines, airplanes, and missiles, and is even gaining a previously unknown capability to attack distant land targets.

All of this not only will permit the surface combatant to perform its traditional escort roles more effectively, but also offers the prospect of a more independent offensive role. If such a role develops, this would restore to the surface combatant force some measure of the status in naval strike forces that it enjoyed before World War II. An independent offensive strike role for surface combatants, however, would almost certainly come as a supplement, and a complement, to aircraft carriers, not as a substitute for them. Despite the impressive capabilities of cruise missiles, they carry relatively small payloads (for conventional explosives) and do not have the operational flexibility of a manned aircraft. It is unlikely that non-nuclear cruise missiles will be able to provide the critical mass of offensive firepower needed for major engagements at sea or for major force projection missions ashore. In less-demanding mission scenarios, however, the surface combatant's new capabilities may permit it to perform tasks that now are carried out by carriers.

The value of these capabilities and, indeed, of the capabilities of other naval forces as well must ultimately depend upon their usefulness in accomplishing the Navy's missions. 18/ A major issue before the Congress therefore will be what kind of ships and how many of each will provide the best overall capability in the years ahead. The following chapter presents an illustrative group of program alternatives that respond to different views of how best to accomplish the Navy's missions.

18/ For a discussion of naval mission priority alternatives, see Congressional Budget Office, Shaping the General Purpose Navy of the Eighties: Issues for Fiscal Years 1981-1985 (January 1980), Chapter II.

CHAPTER IV. U.S. SURFACE COMBATANTS: PROGRAMS FOR THE 1990s

In considering future naval shipbuilding programs, the Congress faces broad and often difficult choices in selecting for funding, within the inevitable budgetary constraints, those programs that will best enhance U.S. naval power. These choices depend upon a judgment as to what capabilities are most important for future naval forces, and that, in turn, depends upon a judgment about future naval strategy and the character of future naval warfare. This chapter analyzes the ways in which surface combatants embodying the technological advances discussed in Chapter III might contribute to future naval forces, and the role that they might play in naval strategy. The chapter concludes with a discussion of four alternative shipbuilding programs that reflect differing perceptions of naval strategy and its requirements for surface combatants.

THE NAVY'S VIEW: CARRIER BATTLE GROUPS ARE KEY TO VICTORY, BUT SURFACE COMBATANTS ARE ALSO USED IN OTHER ROLES

The Navy believes that the most efficient way to gain and maintain control of the seas is to destroy hostile forces capable of challenging that control. 1/ Carrier battle groups would be used as the instrument of such offensive action. The Navy believes that the very existence of such offensive forces would force the Soviets into a defensive, reactive mode, allowing the United States to capitalize on Soviet geographic disadvantages and compelling the Soviets to concentrate their naval forces in areas close to the Soviet Union where they would pose less of a threat to U.S. sea lines of communication. 2/ Surface combatants would play a key role in these battle groups by providing a

1/ Testimony of Admiral Thomas B. Hayward, USN, Chief of Naval Operations, in Military Posture and H.R. 6495, Hearings before the Subcommittee on Seapower and Strategic and Critical Materials, House Committee on Armed Services, 96:2 (February and March 1980), Part 3, p. 361.

2/ Ibid.

defense in depth, enabling the carriers to withstand the intensive counterattacks that would attend this strategy. In addition, surface combatants equipped with cruise missiles could contribute to the battle group's offensive punch.

The usefulness of carrier battle groups would by no means be limited to direct confrontations with the Soviets. In the Korean War and again in Vietnam, aircraft carriers were heavily involved in conducting tactical air strikes and providing air support for ground forces. A recent Brookings Institution study examined the actual use of military forces in promoting U.S. political objectives in the period 1946-1975 and found that naval forces were involved in 177 of 215 incidents examined, more than half of which involved aircraft carriers. 3/ Carriers remain the only means of very quickly aggregating a substantial amount of tactical air power on short notice in most areas of the world. Carrier battle groups are therefore an important instrument of national power in a wide range of conflict scenarios, including Third World crisis situations, and can be expected to remain so for the foreseeable future.

Surface action groups (SAGs), which are naval combat units that do not contain an aircraft carrier, are used today in the Middle East and the Caribbean, and might be a form of response appropriate to other crises in the Third World. Their offensive capability will be considerably enhanced by the availability of cruise missiles and might be further enhanced in the future by deployment of V/STOL aircraft aboard small carriers or "air-capable" ships. The concept of a surface action group gives the surface combatant an independent offensive mission once again; if successful, it will provide the Navy with additional flexibility in the employment of its forces.

In addition to these offensively oriented roles, the Navy expects surface combatants to continue their important defensive roles as escorts for underway replenishment groups and convoys, as well as their traditional offensive/defensive role in support of amphibious operations. In each of these roles, the future surface combatant will be faced with more formidable threats, but it will be aided in performing its missions by better weapons and sensor systems.

3/ Barry M. Blechman and Stephen S. Kaplan, Force Without War (Washington, D.C.: The Brookings Institution, 1978), p. 38.

THE BATTLE GROUP OFFENSIVE STRATEGY: ARE THERE PITFALLS?

Current Navy strategy places primary emphasis on the battle group as the basis of naval power. In the event of a full-scale war between the United States and the Soviet Union, battle groups would be the primary offensive strike arm for conducting a frontal assault against Soviet naval forces and bases. This strategy, however, is by no means the only one the Navy may be called upon to execute in the future. Depending upon the circumstances at hand, the national command authority may find it advisable (because of the nature of the crisis, the disposition of Soviet forces, agreements made with allied nations, etc.) for the Navy to pursue some strategy other than a frontal assault on Soviet home bases. The Navy may be required to face a distributed threat by Soviet and/or other naval forces that would require a different mix of ships, including a sufficient number of surface combatants to protect U.S. interests over a relatively long period of time in distant waters. Indeed, recent events in the Middle East have been of this nature, straining the Navy's resources with demands for further standing force deployments.

In addition, some have questioned whether an approaching carrier battle group, with its enormous concentration of power, might induce the Soviets to use nuclear weapons against it. Certainly the temptation would be great, given the difficulty of defeating a battle group with conventional weapons. In addition, use of nuclear weapons at sea would involve minimal collateral damage; it would therefore be a clearcut tactical employment exclusively against military forces.

Even if one takes the most pessimistic view of the prospects for using battle groups to attack Soviet bases, the need for aircraft carriers and their associated surface combatants does not necessarily collapse, although the strategy for their employment may change. If the Navy is prevented from making a frontal assault on enemy naval forces in their basing areas because of factors relating to a particular conflict situation, because of concern about nuclear escalation, or for any other reason, then the strategy of winning through quick destruction of the enemy's naval forces and supporting base structure may have to be revised. In such a situation, a more gradual attrition of enemy forces and a wider distribution of naval forces may be necessary. In this kind of war, or in a war focused in some area of the Third World, a massive, coordinated attack such as the Soviets could organize near their home waters might not materialize, but the U.S. Navy could be faced with the task of

opposing the interdicting Soviet naval forces worldwide. In such circumstances, having ships with sufficient capability to withstand the maximum Soviet home-water threat may be less important than having enough ships to oppose a distributed threat in distant waters. 4/

SURFACE COMBATANT SHIP DESIGN ALTERNATIVES

Four different types of surface combatants are discussed in the following section. Employing many of the new technologies discussed in Chapter III, each would have formidable combat capabilities as compared to current warships. The four ship types represent a range of alternatives illustrating how ship design trade-offs can affect the cost, capability, and mission orientation of a warship. Considerations bearing upon such trade-offs are discussed in more detail in Appendix C; an example of how design trade-offs affect ship size and cost is provided in Appendix D. A decision by the Congress as to what mix of these ships to authorize will depend upon its view of future naval requirements. The contributions of these different ship types to alternative naval strategies will be examined at the conclusion of this chapter.

Current Program Surface Combatant Types

AEGIS Cruiser (CG-47). Of all existing or authorized surface combatants, the CG-47 can best meet Navy combat system requirements. Not only will it provide the formidable AAW capability of AEGIS, but it will also have the best available ASW sensors, LAMPS III helicopters, two five-inch guns, ASROC weapons, and cruise missiles, with their long-range strike capability. Only the fact that it is not nuclear powered makes the CG-47 less than a first-line warship in every way. The proven hull and machinery of the existing DD-963 should, however, provide a reliable and capable platform for this powerful combat system. The CG-47 will be an expensive ship, with an estimated unit procurement cost of $1.02 billion (fiscal year 1982 dollars).

4/ For a discussion of naval mission priority alternatives, see Congressional Budget Office, Shaping the General Purpose Navy of the Eighties: Issues for Fiscal Years 1981-1985 (January 1980), Chapter II.

New-Design Battle Group Destroyer (DDGX). The DDGX is intended by the Navy to be a battle group surface combatant, contributing both offensively and defensively to battle group capabilities but costing sufficiently less than the CG-47 to allow procurement in adequate numbers. It is currently in the early design stages, and decisions on its final configuration are subject to revision by the Navy as the design process proceeds.

The design for the DDGX is driven by the requirements of the Navy's hypothesized battle group scenario. In this scenario, a battle group would be exposed to an intensive, coordinated attack by aircraft, submarines, and surface ships in which an enemy could launch hundreds of cruise missiles accompanied by intensive electronic countermeasures (ECM). Given this threat, the Navy believes that the DDGX should have a very good AAW capability, with high resistance to jamming, fast reaction time, and high firepower. Its missiles will be launched from the newly developed Vertical Launching System (VLS), which will provide quick reaction time in AAW and flexibility for launching a variety of missile types, such as Tomahawk and ASROC, in addition to AAW missiles. The DDGX will not be fitted with a towed-array sonar, nor will it carry LAMPS helicopters since the Navy assumes these would be available on other ships in the battle group. It will, however, have the electronics necessary to work with LAMPS III, and will be fitted with an emergency landing pad. Its ASW capabilities will be oriented toward active sonar screening, using the large, low-frequency SQS-53 sonar system and the ASROC ASW weapon. The DDGX is being designed to a cost goal of $500 million (fiscal year 1981 dollars) for each follow-on ship after the lead ship.

Additional Types: Higher- and Lower-Cost Alternatives

Two hypothetical alternative surface combatants will be described as illustrative of higher- and lower-cost alternatives to current Navy ship designs.

Nuclear Cruiser (CGN). A nuclear-powered AEGIS cruiser would provide the combat capabilities of the CG-47, together with the additional operational flexibility inherent to the unlimited steaming range of nuclear power. The ship hypothesized here would employ the basic hull and machinery of the Virginia-class (CGN-38) cruiser and would be an updated version of the "improved Virginia class" first proposed to the Congress in the fiscal year 1976 program. The Navy has developed plans for a ship of this type, designated CGN-42. The fiscal year 1978 budget provided $180

million for advance procurement of nuclear components and engineering for the CGN-42, but no further work has been authorized. The CGN-42 was to have basically the same combat system as the CG-47. Being a substantially larger ship, however, it would have greater growth potential as well as the unlimited steaming endurance of nuclear power. The CGN-42 would thus represent a surface combatant with the best capabilities currently achievable. It has been estimated by the Navy that a ship of this kind would cost about $1.43 billion for the lead ship and $1.23 billion for follow-on ships (fiscal year 1981 dollars). 5/

Open Ocean Destroyer (DDGY). This ship, which for convenience is designated DDGY, is illustrative of a warship that would result from different choices on the design trade-off issues discussed in Appendix C. It would be an offensively oriented surface combatant capable of battle group operations, but optimized more for broad ocean operations in the context of a worldwide naval war rather than for the intensive, frontal assault scenario used to derive the DDGX requirements.

The DDGY would carry the same vertical launching system and the same missiles, including cruise missiles, as the DDGX. It would be significantly smaller than the DDGX, however, because of the effect of the design trade-offs discussed below and because, unlike the DDGX, it would not have space and weight capacity for unspecified future growth. 6/

5/ Testimony of Vice Admiral James H. Doyle, Jr., USN, Deputy Chief of Naval Operations for Surface Warfare, in Military Posture and H.R. 6495, Hearings, Part 3, pp. 118-19. The prices given for the CGN include initial nuclear fuel equivalent to about 3 million barrels of oil for a conventionally powered ship.

6/ Provision of space and weight for future growth is a relatively recent development in U.S. design practice. In addition, U.S. designers use relatively large "margins" in their designs. Margins are allowances for unforeseen growth as design and construction progress. These practices tend to produce larger ships for a given payload than would be built in countries such as the Soviet Union or Italy where such allowances are much more austere. For a discussion of this, see J.W. Kehoe, C. Graham, K.S. Brower, and H.A. Meier, "NATO and Soviet Naval Design Practice, Eight Frigates Compared," International Defense Review (7/1980), pp. 1003-10.

In AAW, the DDGY would emphasize "back-end" technology and would use an advanced missile fire control system to achieve high firepower at shorter ranges. It would use the advanced SM-2 AAW missile and would have the long-range area AAW capability of that missile. 7/ Although this system would probably be less capable, particularly in a jamming environment, than the one proposed for the DDGX or AEGIS, it should be considerably less expensive than AEGIS and much more capable than any of the pre-AEGIS AAW systems on existing cruisers and destroyers.

In ASW, the DDGY emphasizes long-range passive detection with a towed-array sonar whereas the DDGX emphasizes active detection using the SQS-53 sonar. The DDGY would also be fitted with an active sonar, but would utilize the smaller SQS-56 rather than the larger, more expensive SQS-53 carried by the DDGX. The DDGY would carry two LAMPS III helicopters, which are essential to its long-range ASW orientation and would also provide it with an independent over-the-horizon surveillance and targeting capability.

The DDGY is assumed to have the same propulsion system as the DDGX; but being a smaller ship, it would be a bit faster. Its range, however, would be about 10 percent less than that of the DDGX.

Finally, the DDGY would be fitted with a gun and a relatively simple gun fire control system suitable for surface engagements and shore bombardment. Although a gun is unlikely to be useful in a modern battle group engagement, it could still be vital for independent patrol and presence operations and for support of amphibious landings.

Emphasizing long-range towed-array ASW rather than shorter-range active sonar, carrying its own helicopters rather than relying upon those from other ships, and mounting a large-caliber

7/ This concept assumes that high firepower is achieved through the use of the ICW and agile beam illuminator technology described in Chapter III. At long range, the multiple-target engagement technique could not be used because of power limitations. Long-range engagements do not, however, normally have the time urgency of short-range engagements.

gun for antisurface and shore bombardment missions, the DDGY would be better equipped for independent operations outside of the battle group than would the DDGX.

In addition to carrier battle group operations, the DDGY could operate with surface action groups. In this role, its aircraft would provide over-the-horizon surveillance and its towed-array sonar would provide long-range detection of submarines. The DDGY could also operate in support of amphibious landings, providing AAW and ASW protection en route and gunfire support during the assault. It could also operate with frigates in escorting replenishment ships and convoys, substantially increasing the protection provided. Finally, the DDGY could operate independently in patrol and presence or ocean area control missions.

The DDGY would, however, have less capability in its air search radar than the DDGX. The DDGY's AAW capabilities would nevertheless be very good in any but the highest-threat environments, and in future battle groups it would have the advantage of data-linked air target information from the DDGX and AEGIS ships.

Using the size and cost impact estimating factors presented by the Navy in discussing various destroyer trade-off issues, it is estimated that the DDGY would have a full-load displacement of about 5,000 tons and a follow-on ship cost of about $375 million (fiscal year 1982 dollars). Its size and cost rationale is outlined in Appendix D.

Principal characteristics of these four designs are shown in Table 3, and their external profiles are shown in Figure 5.

PROGRAM ALTERNATIVES

The four ship types described above are representative of a spectrum of alternative surface combatant warship designs that could be built in the next decade and beyond. The CGN is a high-quality general-purpose warship with emphasis on capability as opposed to cost considerations. The CG-47 provides essentially the same combat system capability as the CGN but at a significantly lower cost, since the ship is both smaller and conventionally powered. The destroyer designs, DDGX and DDGY, would have somewhat less capability than either of the cruisers but would be less expensive and therefore available in

larger numbers for any given level of investment. The DDGX is optimized for battle group operations, and the DDGY is illustrative of a ship somewhat less optimized for battle group operations in the interest of providing a better broad-ocean, independent-operations capability.

Choosing which ships to build among these alternatives, and how many of each to procure, depends upon perceptions about future naval combat. If one believes that offensive strikes against enemy forces and bases in their home waters is the optimal strategy in war, and that this strategy can actually be executed in most contingencies leading to war, then emphasis should be given to procuring high-quality ships designed for the highest threat level.

If, however, one believes that a frontal assault in enemy home waters is not the optimal strategy, or that it might lead to nuclear escalation, then emphasis might better be given to procuring additional ships for the funds available.

In either case, however, high-quality ships would have a role to play. Difficult and dangerous combat missions occur in almost any war, and the best possible capabilities may be essential for success in such situations. The issue is one of emphasis, and of the extent to which high quality justifies having fewer ships than might otherwise be obtained for a given level of investment.

Beyond the quality-versus-quantity issue lies that of how to balance the overall capabilities of the fleet. Should a large number of ships of a single design be procured, or would it be better to procure different designs, each offering a different mix of capabilities? 8/ The answer to these questions also depends upon one's view of the future and upon the degree to which one prefers to hedge against a range of contingencies rather than focusing on a single contingency. The next section outlines four hypothetical 10-year shipbuilding programs that illustrate different approaches to these decisions.

8/ For a discussion of strategy options relevant to these considerations, see Congressional Budget Office, Shaping the General Purpose Navy of the Eighties: Issues for Fiscal Years 1981-1985, pp. 7-19.

TABLE 3. CHARACTERISTICS OF ALTERNATIVE SHIP TYPES

	Nuclear Cruiser (CGN-42)	AEGIS Cruiser (CG-47)	Battle Group Destroyer (DDGX) a/	Open Ocean Destroyer (DDGY) b/
Displacement (tons)	12,000	9,100	6,000	5,000
Maximum Speed (knots)	30+	30	29	30
Endurance Speed (knots)	--	20	18	20
AAW Systems				
Search radar	SPY-1	SPY-1	MFAR	3-D c/
Fire control radar	4 MK99	4 MK99	2 MK99 or 2 Agile Beam	2 Agile Beam d/
Launcher system	VLS	VLS	VLS	VLS
Missile capacity	122	122	90	90
Missile type	SM-2	SM-2	SM-2	SM-2
ASW Systems				
Towed-array sonar	SQR-19	SQR-19	None	SQR-19
LAMPS-compatible	Yes	Yes	Yes	Yes
Number of aircraft	Two	Two	None	Two
Hull-mounted sonar	SQS-53	SQS-53	SQS-53	SQS-56
ASW weapons	ASROC/MK32 Tubes	ASROC/MK32 Tubes	ASROC/MK32 Tubes	ASROC/MK32 Tubes
ASuW Systems				
Missiles	Tomahawk (TASM)	Tomahawk (TASM)	Tomahawk (TASM)	Tomahawk (TASM)
Guns	Two 5"/54	Two 5"/54	None	One 155mm (6")
Land Attack Systems				
Missiles	Tomahawk (TLAM)	Tomahawk (TLAM)	Tomahawk (TLAM)	Tomahawk (TLAM)
Guns	Two 5"/54	Two 5"/54	None	One 155mm (6")
Estimated Cost (millions of fiscal year 1982 dollars)	$1,340	$1,018	$550	$375

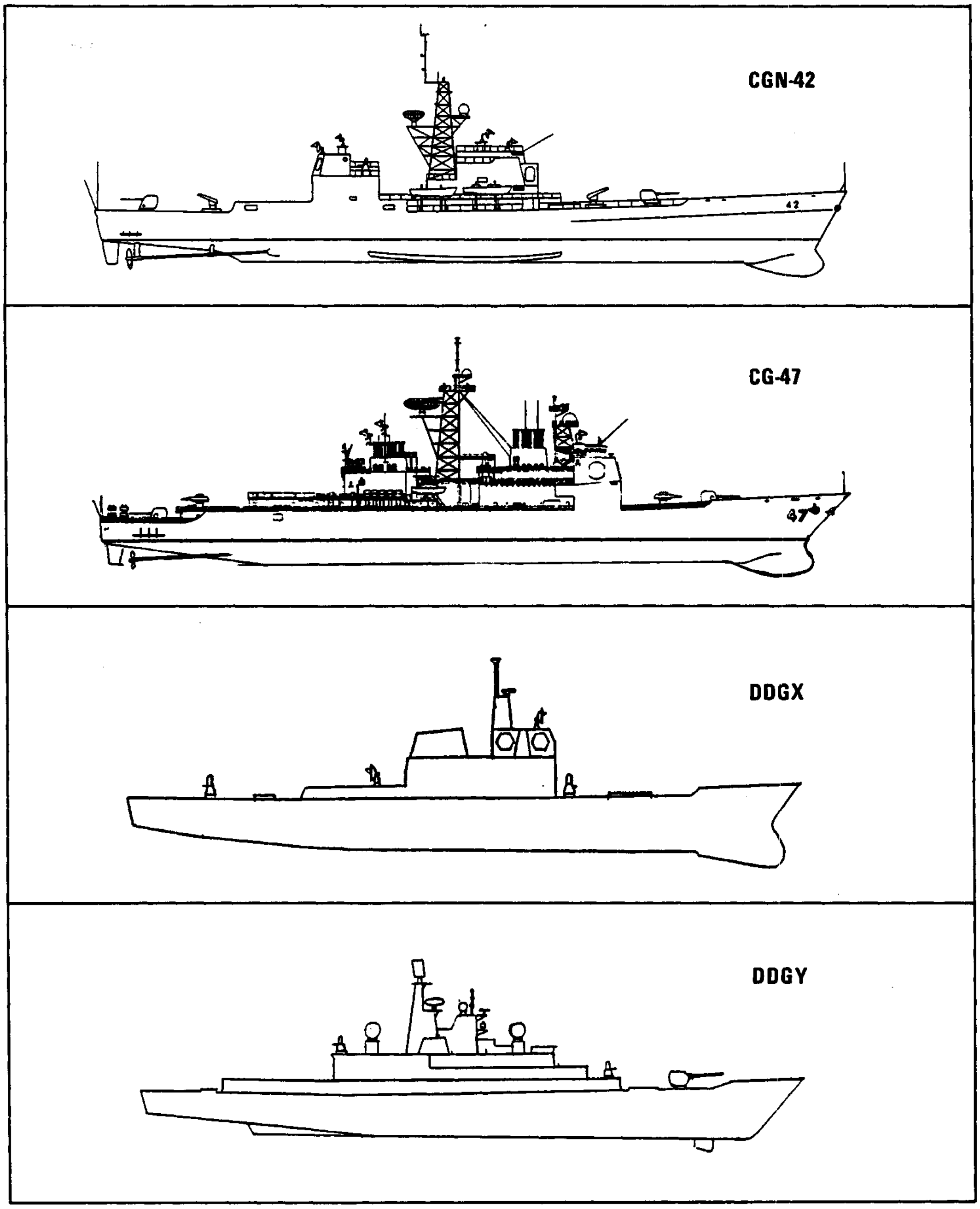
a/ A final decision on the configuration of the DDGX has not yet been made. The characteristics listed above may be changed by the Navy as the design process progresses.

b/ For DDGY weight and cost rationale, see Appendix D.

c/ SPS-48E 3-D and SPS-49 2-D air radars as used on the latest U.S. ships supplemented by horizon and high-elevation search by agile beam fire control radars. Later units might have a new-generation air search radar.

d/ Agile beam is used here as a generic term that includes such specific concepts as the Terminal Engagement Radar (TER) or Flexible Adaptive Radar (FLEXAR). This system would be capable of simultaneously tracking and engaging multiple targets while supplementing the air search function in the horizon and zenith areas.

Figure 5.
Four Alternative Ship Types



Budget Options: Equal-Cost Alternatives but Differing Force Levels

The four program options shown in Table 4 illustrate a range of approaches to providing a fleet of modern, capable surface combatants for the Navy of the 1990s. Each of these options is calculated to require roughly $33 billion (in fiscal year 1982 dollars) in new construction funds during the period 1986-1995. This is equivalent to CBO's estimate of the cost of the program recommended by the Navy (Option II) in testimony to the Congress in February 1980. The life-cycle costs of the four options are also fairly close. 9/ Each assumes that construction of a total of 18 CG-47-class ships is approved through 1985. 10/

The options have different consequences as to the number and types of ships that would be at sea in the fleet in the year 2000. The force level and force structure resulting from each of the options are displayed in Figure 6--the dashed line

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9/ Life-cycle costs among the four options vary about ±5 percent from the average when outyear operating costs are discounted to the acquisition year. When outyear operating costs are not discounted, the life-cycle cost of Option I, with the smallest number of ships, is about 20 percent lower than that of Option IV, which has the largest number of ships. The life-cycle costs of Options II and III fall between those of Options I and IV.

10/ The options have been structured to have equal cost in order to provide a common basis for objective comparison. Another approach might have been to attempt to define equal-effectiveness options and compare their costs, but effectiveness is difficult, at best, to define and impossible (in a way that all could agree upon) for such complex issues as long-term ship procurement programs. Alternatively, the options might have been structured to meet some set of "requirements" derived from different sets of mission assumptions. This approach would be equally subjective and contentious, however, since the validity of the assumptions underlying such requirements could only be established by future events. The options are therefore structured on the best available objective measure, acquisition cost, the cost chosen being that needed to procure the most authoritative current requirement--that of the Navy's requirement estimate.

Figure 6.

Battle Group Surface Combatant Force Levels and Structures in the Year 2000: Four Equal-Cost Alternatives

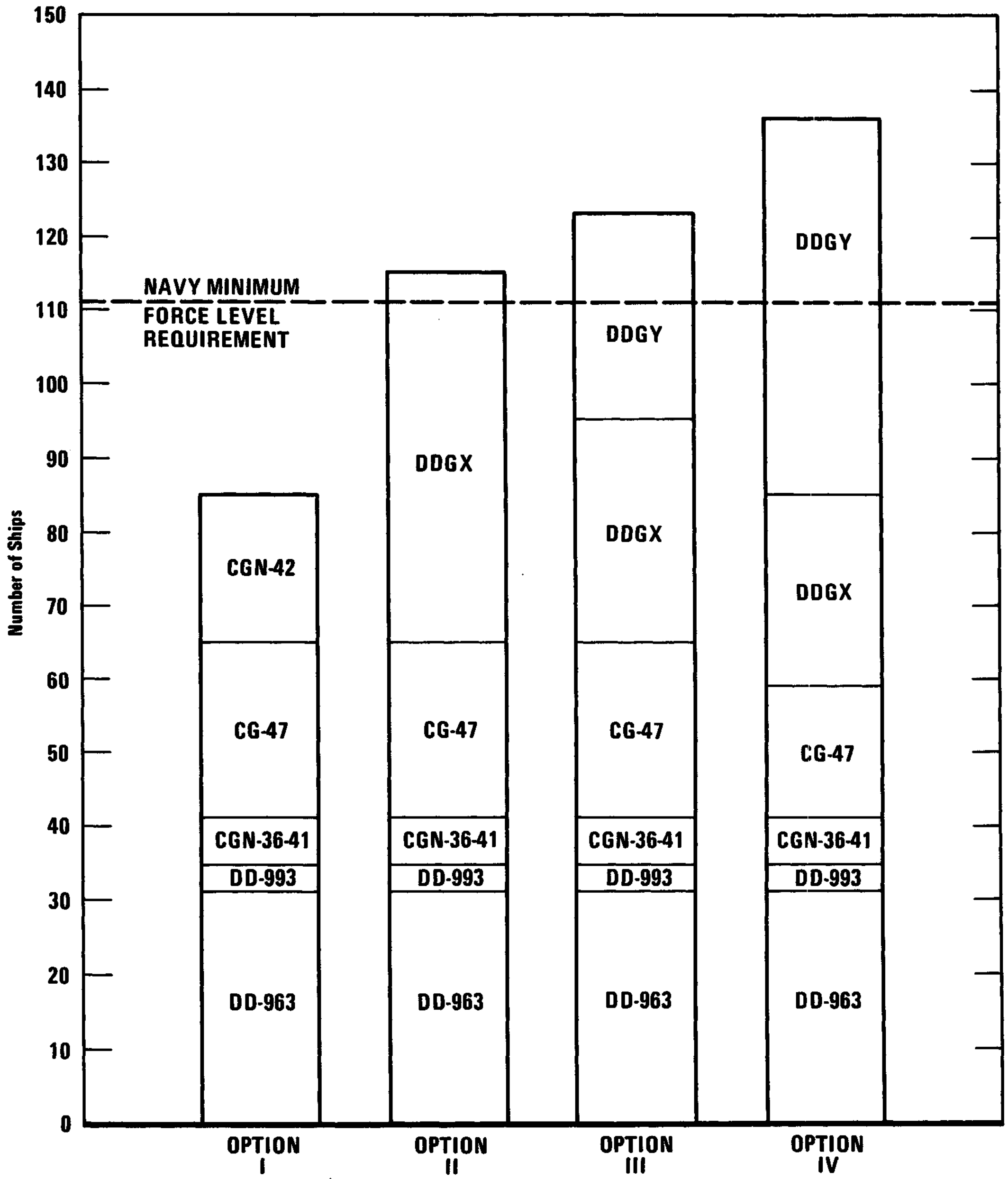

TABLE 4. ILLUSTRATIVE $33 BILLION 10-YEAR PROGRAMS FOR SURFACE COMBATANT WARSHIP CONSTRUCTION, FISCAL YEARS 1986-1995

Option	Ship Type	New Ships Authorized: In 1985 or Earlier	New Ships Authorized: In 1986 Through 1995	New Ships Authorized: Through 1995	Percent of Current Force Level at Sea in Year 2000
Option I:					
Emphasize	CGN-42	0	20	20	77
Capability	CG-47	18	6	24	
				44	
Option II:					
Emphasize Battle	CG-47	18	6	24	105
Group Operations	DDGX	1	49	50	
				74	
Option III:					
Balance Battle	CG-47	18	6	24	113
Group and Other	DDGX	1	29	30	
Mission Emphasis	DDGY	0	29	29	
				83	
Option IV:					
Emphasize Broad-	CG-47	18	0	18	124
Ocean Distributed-	DDGX	1	25	26	
Force Operations	DDGY	0	51	51	
				95	

indicating the Navy's force level requirement as stated in February 1980. Knowledgeable observers may disagree with this requirement, and even the Navy has characterized it as only a minimum acceptable level. Choosing among the options must therefore depend upon judgments about effectiveness and naval strategy. Arguments supporting each option are presented below.

Option I: Emphasize Capability

Option I is consistent with the view that warships should have the highest capabilities achievable at the time of their design and construction. The advocate of this option accepts the Navy's view that the key to victory in a future war will be

offensive strikes into enemy waters to destroy the enemy's forces and basing structure. Realizing that this strategy would almost certainly stimulate maximum resistance, he sees no alternative to building ships that can survive and be capable of winning in that situation. Although sympathetic to the need for more ships, the advocate of Option I is skeptical of claims that compromises on capability in the interest of lower cost would yield more overall fleet effectiveness. Nevertheless, he is willing to concede that the already established CG-47 program should proceed, despite its lack of nuclear power, because of its formidable combat capability and because it is necessary in order to continue ship production in the near-to-intermediate term. New programs, however, should provide ships with the best possible capabilities, including nuclear power. He therefore supports establishing a program to build nuclear cruisers having the best available weapons and sensor systems.

Option II. Emphasize Battle Group Operations

The advocate of Option II also accepts the Navy's offensive strike strategy and wants the best capabilities available for surface combatants, but he regards the "no-compromise-on-capability" approach of Option I as unrealistic and likely to result in a dangerously small Navy. He believes that it is not only possible but necessary to make judicious choices in warship design features that will produce less costly ships, but ships that are adequate to their mission and, being less costly, are more likely to be available in sufficient numbers. In making such choices, the advocate of Option II believes that the most appropriate frame of reference is a mission scenario featuring battle group operations against intensive enemy opposition in a forward area. He therefore supports the DDGX program as providing the capabilities most needed in the battle group, given the present and anticipated Navy force mix, at a cost at which sufficient ships can realistically be obtained. This option was favored by the Chief of Naval Operations in 1980 Congressional testimony.

Option III. Balance Battle Group and Other Mission Emphasis

The advocate of Option III agrees with the advocate of Option II that an uncompromising attitude on ship capabilities is unrealistic and likely to lead to a very small Navy. He believes, however, that if it is necessary to build lower-cost ships, they

should be built in a variety of types so as not to overspecialize fleet capabilities. While agreeing with the concept of offensive battle groups and supporting the DDGX as contributing to their effectiveness, he believes some resources should be put into other ship types as well. In addition to battle group operations, he perceives a variety of other tasks facing the Navy, such as extended patrol and presence operations in the Third World, where concentrated battle groups may not be the most efficient or appropriate application of naval forces. He therefore supports putting some resources into the DDGY, which, though capable of battle group operations, is oriented more toward independent and open-ocean operations than the DDGX. This, he believes, will produce a better balance of capabilities against the uncertainties of the future than buying only the DDGX.

Option IV. Emphasize Broad-Ocean Distributed-Force Operations

Like the advocates of Options II and III, the advocate of Option IV believes a judicious selection must be made in ship capabilities to obtain adequate numbers as well as adequate capabilities. He recognizes the importance of tactical air power and supports the concept of carrier battle groups. He is less convinced than advocates of the previous options, however, that a frontal assault by battle groups in enemy waters is the best strategy for a future war. He believes that, for a variety of reasons, it is more likely that a future naval war will involve worldwide operations against a much more distributed threat than the concentrated forces of the battle group scenario. Although favoring the DDGX program as necessary to support battle group operations in the 1990s, he perceives a high utility for more numerous, independently operating naval groups and therefore supports putting relatively more emphasis on the DDGY.

Options Versus Requirements: How Much is Enough?

The force level requirements presented to the Congress in 1980, and described in Chapter II, represent a reduction from previous estimates of surface combatant force level requirements. These new requirements, therefore, show a gravitation toward the view that individual ship capability rather than numbers of ships should govern in force planning and ship procurement decisions. Nevertheless, the Navy has frequently stated that it

has difficulty in meeting its commitments with the number of ships it has available. 11/ The tension in the Middle East has significantly increased demands upon the Navy for standing force deployments.

Option I, which places primary emphasis on ship capability, would result in a force of high-quality ships, but one numbering only 77 percent of the current force; thus, it could not simultaneously support all of the functional requirements discussed in Chapter II. Option II, which provides substantially more ships, would result in a force consistent with the requirements stated by the Navy in February 1980 and would be numerically comparable to today's force level. Options III and IV provide successively larger forces for the same investment, with Option IV resulting in a force level approximately equal to the Navy's former objective for cruisers and destroyers. Options III and IV would be more consistent with increased force level requirements brought about by contingencies such as the recent Persian Gulf and Indian Ocean developments.

As discussed in Chapter II, the Navy has stated it needs enough surface combatants to support at least six two-carrier battle groups and several surface action groups, as well as provide escorts for amphibious groups, underway replenishment groups, and convoys. Table 5 shows some implications of Options I through IV for the Navy's ability to support these requirements. The numbers in Table 5 assume that priority is given to battle group requirements. Option I would result in six well-protected battle groups, but would leave few ships for other functions. Option IV, at the other extreme, would provide enough ships to form five surface action groups after providing for battle group requirements, and would provide more ships for escort functions as well.

11/ Admiral Thomas B. Hayward, USN, Chief of Naval Operations, recently stated before the Senate Armed Services Committee that "for the first time in anyone's recollection the U.S. Navy is unable fully to meet its peace-time commitments" and would have to vacate essential areas of the world to respond to an emergency. See "U.S. Has Lost Naval Superiority Over Soviets, Leaders Tell Hill Panel," Washington Post (February 6, 1981), p. 10.

TABLE 5. MISSION SUPPORT IMPLICATIONS OF ALTERNATIVE PROGRAM OPTIONS IN THE YEAR 2000

Mission Capability	Option I	II	III	IV
Number of Two-Carrier Battle Groups Supported	6	6	6	6
Number of Surface Action Groups Supported	0	3	4	5
Number of Amphibious Escort Ships	9	11	13	18
Number of Underway Replenishment Escort Ships	24	32	32	32
Number of Convoy Escort Ships	66	66	68	70

LARGER NAVAL FORCE LEVELS: SOME IMPLICATIONS

The options presented above reflect the Navy's requirements and force level planning as presented to the Congress in 1980 testimony. The $33 billion assumed investment cost for each option is CBO's estimate of the 10-year investment cost of the program (Option II) recommended by the Navy in that testimony.

Recently the Reagan Administration has announced its intention to pursue a more ambitious naval program, including building and maintaining a force of 15 aircraft carriers. 12/ The program

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12/ See "FY 1982 Shipbuilding and Conversion Budget Request," Statement of Vice Admiral William H. Rowden, USN, Deputy Chief of Naval Operations for Surface Warfare, before the Subcommittee on Seapower and Strategic and Critical Materials, House Committee on Armed Services (March 25, 1981; processed). See also "Interview with the Secretary of the Navy," Sea Power (March 1981), pp. 17-30.

proposed by the new Administration includes higher force level goals for other types of ships as well, including a new goal of 137 battle-group-capable surface combatants.

Of the options discussed above, only Option IV provides enough ships to support seven battle groups while meeting the Navy's other mission requirements. Programs to support seven two-carrier battle groups using the force structure approach taken by any of the other options would require an even higher level of investment--about $50 billion over the 10-year period as against the $33 billion investment level used here. At any level of investment, however, whether $33 billion, $50 billion, or some other amount, these options still illustrate two key principles: the ship capabilities needed depend upon one's view of future naval strategy, but an emphasis on high-cost ships reduces the force levels that can be achieved within a given budget.

CONCLUSION: PROVIDING SURFACE COMBATANTS FOR THE NAVY OF THE 1990s IS A PROBLEM FOR TODAY

Although the number of ships in the Navy's surface combatant force is expected to remain relatively stable through the 1980s, the force level will decline abruptly in the 1990s unless future shipbuilding programs are adequate to replace ships being retired. This situation will be especially acute for battle group surface combatants as guided missile destroyers and cruisers commissioned in the 1960s are retired upon reaching 30 years of age. These ships will, furthermore, be entering their third decade of service in the 1980s and may be of limited effectiveness if their combat systems are not upgraded.

Since the design and procurement lead times for modern warships are very long, research and development decisions made in the next year by the Administration and by the Congress can define and constrain ship procurement options in the mid-1980s and, consequently, the ships delivered to the fleet in the 1990s. For Option II to be a real shipbuilding alternative in 1986, funding for design and combat system development for the DDGX must be provided in fiscal year 1982. Similarly, for Options III and IV to be real alternatives, research and development funding for DDGY design and combat system development must also be provided. This would probably require funding of about $100 million to $150 million per year for the DDGX and the DDGY together, depending upon the number and status of ongoing projects.

In addition, the ships currently in the fleet will require periodic upgrading to maintain their effectiveness in a rapidly changing technological environment. This will require continuing research and development funding for modernization programs, such as the CG/SM-2 Upgrade and the New Threat Upgrade programs discussed in Chapter II, as well as funds actually to carry out the upgrades when the new systems become available.

Each of the program options discussed in this report, and almost any alternative program that might be devised, must ultimately depend not only upon a continuing investment in shipbuilding but also upon continuing support of combat system research and development and the maintenance of an adequate industrial base to produce the required ships and weapons systems.

Maintaining an effective surface combatant force in the U.S. Navy to the year 2000 will require a large and sustained commitment of funds from the Congress, not only for constructing the required ships but also for developing the advanced combat systems needed to make them effective. Programs to develop surface combatants for the 1990s should begin now.

APPENDIXES

APPENDIX A. CURRENT U.S. SURFACE COMBATANTS

Among the older surface combatants that can be expected to remain in the fleet through the 1980s are a large group of frigates (62 ships) of the FF-1052 class, the FF-1040 class, and the FFG-1 class. These ships were designed primarily as ocean escort ASW ships, using echo-ranging sonar and short-range ASROC weapons. The six ships of the FFG-1 class were also fitted with the single-channel Tartar anti-air missile system, which permits them to engage only one aircraft at a time. All of these ships were delivered between the mid-1960s and mid-1970s.

The most recent frigate type is the Oliver Hazzard Perry (FFG-7) class, which is now in serial production with a total purchase of about 60 ships contemplated. Designed to have a balanced but relatively modest combat capability, the FFG-7 is intended for relatively low-threat missions. It is equipped with a two-channel AAW missile system based on the MK92 weapon control system that fires Standard-MR (SM-1) missiles. This provides an area AAW capability with modest multiple-target firepower. Performance may be degraded, however, by electronic jamming. The FFG-7 class will also be equipped with two LAMPS helicopters, the SQR-19 TACTAS towed-array sonar, and Harpoon missiles to provide long-range ASW and ASuW capability. These ships are not considered by the Navy to be battle group ships, but rather are intended for such missions as escort of amphibious groups and underway replenishment groups, and patrol and presence operations in high-tension situations around the world.

Current destroyer types include the older DDG-2 (23 ships) and DDG-37 (10 ships) classes. These guided missile destroyers form a substantial portion of the current inventory of battle group surface combatants, but, having been built in the early 1960s, they will soon have seen 20 years of service and their combat systems are now obsolescent.

A more recent destroyer type is the Spruance (DD-963). The 31-ship building program for this class is now nearly complete. At 7,800 tons displacement, the DD-963 is substantially larger than earlier destroyer types and has over twice the displacement of the 3,600-ton FFG-7-class frigates. Despite its size, cost, and general-purpose ("DD") designation, this class has

often been criticized as being deficient in overall combat capability. 1/ It was designed primarily as an ASW ship, using the SQS-53 sonar and ASROC sensor-weapon combination, and is widely acknowledged to be an excellent platform for active-sonar ASW. These ships will be backfitted with the SQR-19 towed-array sonar and the LAMPS III helicopter, which will further improve their ASW capability. As initially outfitted, however, they have only a short-range, self-defense AAW system, and their surface engagement weapons are limited to two five-inch guns. This very modest AAW and ASuW capability has been the basis of much of the criticism of these ships. The Navy plans eventually to increase the AAW and ASuW capabilities of the DD-963 class by installing a new-design AAW system and a Tomahawk missile launch capability in a mid-life upgrade around the end of the 1980s. 2/

The USS Kidd (DD-993) class (four ships) is a more capable variant of the DD-963 class that came to the U.S. Navy following the fall of the Shah in Iran. These four ships had been ordered by Iran but were cancelled in the wake of the revolution. The Congress then approved their purchase for the U.S. Navy. Essentially a DD-963 destroyer, the DD-993 also incorporates a capable area AAW system using two MK74 missile fire control systems, two MK26 missile launching systems, and the Standard-MR (SM-1) missile.

The most recent class of surface combatant to be authorized is the Ticonderoga-class (CG-47) cruiser (formerly called the DDG-47-class destroyer). The CG-47 will have the same basic hull and machinery as the DD-963. It will be equipped, however, with the AEGIS weapon system and the new SM-2 version of the Standard missile, which will provide it with a formidable AAW capability. It will also be equipped with Tomahawk cruise missiles, LAMPS III helicopters, and the basic DD-963 ASW equipment.

1/ For example, see Captain Robert H. Smith, USN, "A United States Navy for the Future," United States Naval Institute Proceedings (March 1971), pp. 18-25.

2/ See testimony of Honorable David E. Mann, Assistant Secretary of the Navy for Research, Engineering, and Systems, in Department of Defense Appropriations, Fiscal Year 1981, Hearings before the Subcommittee on Defense, Senate Committee on Appropriations, 96:2 (March and April 1980), Part 4, p. 12.

The active cruiser force consists of 27 guided missile ships built over the past 20 years, nine of which are nuclear powered (CGN). In addition to their AAW missile systems, these cruisers also have large active-sonar systems and ASROC weapons for ASW. The last of the once considerable number of World War II-era big-gun cruisers have now been retired.

APPENDIX B. CURRENT ANTI-AIR WARFARE UPGRADE PROGRAMS FOR SURFACE COMBATANTS

THE CG/SM-2 UPGRADE AND NEW THREAT UPGRADE (NTU) PROGRAMS

The CG/SM-2 Upgrade program accomplishes basic modifications necessary to permit a ship to use the new SM-2 (Block I) missile and thus obtain the added AAW range and firepower made possible by the SM-2. Firepower, a very important factor in countering the growing cruise missile threat, will be essentially quadrupled by this modification.

The New Threat Upgrade program builds upon the CG/SM-2 Upgrade program by providing further radar and fire control improvements. It also gives the ship a capability to use the SM-2 (Block II) missile, a faster and still more capable version of the SM-2 AAW missile.

The CG/SM-2 Upgrade and New Threat Upgrade programs are applicable to 41 ships: all of the existing cruisers, the four ships of the DD-993 class, and the 10 ships of the DDG-37 class. (The CG/SM-2 upgrade is a prerequisite to the NTU program.) Some of these ships currently have updated Terrier (MK76) AAW systems; others have Tartar (MK74) systems. 1/ The CG/SM-2 Upgrade will cost about $8 million per ship for the Terrier ships and about $20 million per ship for the Tartar ships. The New Threat Upgrade will cost an additional $18 million per ship. Thirty-one ships are currently programmed to receive both upgrade programs. Not currently programmed for either upgrade are the 10 ships of the DDG-37 class, despite the fact that these ships are equipped with the MK10 missile launching system, which permits use of an extended-range booster on AAW missiles. These ships would therefore have an extraordinarily long-range AAW capability if they were modified to use the SM-2 missile. Although the DDG-37-class

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1/ Thirty-one ships are equipped with the Terrier (MK76) missile fire control system--all of the cruisers except the last six (CGN-36 through 41) and the DDG-37-class destroyers. Ten ships (the six latest CGNs and four DD-993s) have Tartar (MK74) missile fire control systems.

is relatively old (commissioned in 1960 to 1961), installing just the Basic CG/SM-2 Upgrade package at the modest cost of about $8 million per ship would provide the fleet with badly needed long-range AAW capability with the SM-2 missile on 10 additional ships during the period necessary to build new surface combatants.

THE DDG-2 UPGRADE

The DDG Upgrade program, applicable to all ships of the DDG-2 class, updates the present DDG-2 combat system to a digital computer-controlled basis but does not make the system compatible with the SM-2 missile. The firepower and engagement envelope of the DDG-2s will, therefore, remain governed by the capabilities of the Standard SM-1 missile. The DDG-2 Upgrade Program is relatively expensive, however, and only six of the 23 DDG-2s in the fleet are now scheduled to receive this upgrade package. The six-ship program will cost about $200 million per ship and will include combat system improvements beyond those for the AAW system alone, as well as hull and machinery overhaul items costing approximately $50 million.

APPENDIX C. SURFACE COMBATANT TRADE-OFF ISSUES

Warship design inevitably involves numerous trade-offs that affect the final size, capability, and cost of a ship. These trade-offs are generally made within the Navy, and the resulting design is proposed to DoD and then to the Congress for authorization and funding. Some of the major design trade-off issues considered by the Navy during the design process are described below.

SHOULD A SHIP BE GENERAL PURPOSE OR SPECIALIZED?

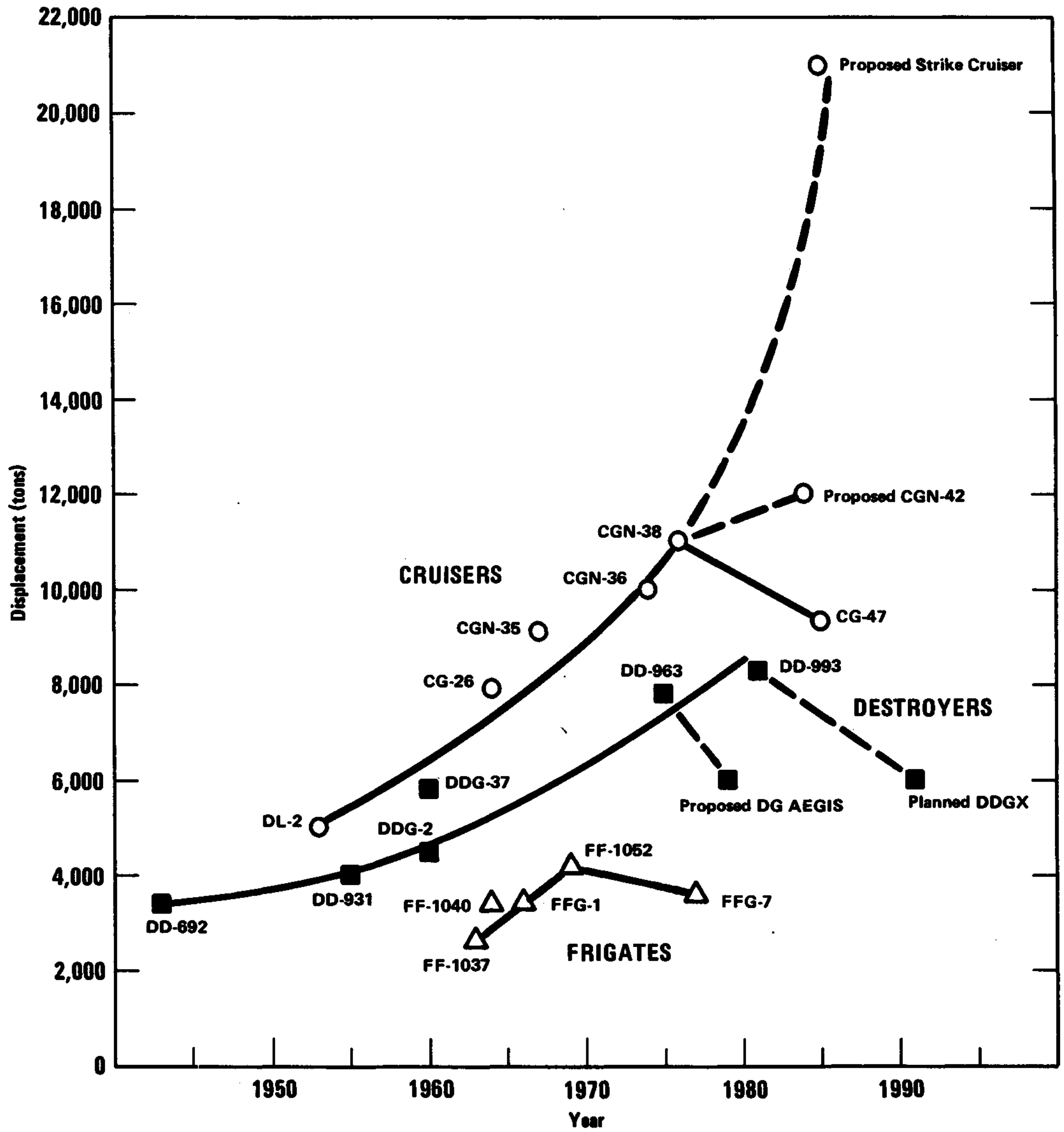
It is probably fair to say that most naval officers would prefer a general-purpose ship that will perform well against any kind of opposition, whether from aircraft, surface ships, or submarines. A prime example of such a ship is the CG-47. The high cost of these ships, however, often forces compromises in the interest of affordability. These can take the form of specialization--that is, emphasizing one kind of capability over another--as was done in the DD-963 and FF-1052 classes, in which ASW capability was stressed. Alternatively, a ship can be designed to have a more balanced capability but at a lower performance level, as was the case with the FFG-7 class. Decisions in this regard turn on the missions of a ship and how best to optimize overall fleet capability.

HOW LARGE SHOULD A SHIP BE?

While the size of a ship is determined by many factors in the design process, it is generally true that more capability requires a larger ship. The growth trend of U.S. surface combatants since World War II is shown in Figure C-1. An increase in displacement over time is quite clear, although there is some evidence of a falling off in the growth trend with respect to the most recent ships. Costs, as measured in constant dollars, have shown a parallel growth over time. Since large ships offer unquestionable advantages in endurance, sea-keeping ability, survivability, and growth potential, and since the cost of

Figure C-1.

Growth Trends for U.S. Surface Combatants



SOURCE: U.S. Navy

an extra pound of ship is relatively low 1/ in comparison with the cost of an extra pound of payload, many believe that large ships are a good investment. Others, however, contend that a ship should be only as large as is necessary to carry its design payload and to obtain its required performance. Since one does not attack the enemy with growth potential, they argue, burdening a ship with unnecessary size is inefficient.

WHAT CAPABILITY TRADE-OFFS SHOULD BE MADE?

Capability improvements almost always involve additional costs. These costs are manifested not only in the acquisition cost of a ship's weapons and equipment but also in their effect on the size of the ship required to carry them. For example, high-capability AAW may have a large impact on cost but only a modest effect on ship size, whereas a large active sonar like the SQS-53 has a substantial impact on both cost and size. Features such as additional endurance and survivability normally affect a ship's size much more than its cost.

AAW Trade-Offs

While the Navy's new AEGIS air defense system would seem to be an obvious choice for AAW in a new surface combatant, the system has several disadvantages. Foremost among these is its cost. Another disadvantage is that the current version of AEGIS, which has been in development for more than 10 years, now lags behind the latest technological advances. During the long AEGIS gestation period, technology has improved to the point that it is now possible to build a lighter, cheaper system that would provide better performance. 2/

1/ A breakdown of the acquisition cost of a typical modern surface combatant shows that the ship platform accounts for about 43 percent of the ship's cost and 91 percent of its weight. The combat system, on the other hand, accounting for only 9 percent of the ship's weight, represents about 57 percent of its cost.

2/ Development of such a system, commonly called the AN/SPY-1B radar, has been proposed, and studies funded by the Navy have identified specific reductions in cost and weight and specific performance improvements that can be made.

Actual development of such a system, however, would require additional time and development funds. If a new AAW system were to be developed, it could either be a reengineered version of the current system or a completely new system using updated AEGIS technology. While a reengineered version may save development time and money, a completely new system could have different operating parameters, most notably transmitter frequency, which would greatly complicate the job of jamming a future battle group containing both AEGIS and a new system. For this and other reasons, the Navy is giving serious consideration to a new phased-array radar for the DDG X that would be similar to the AN/SPY-1 AEGIS radar but would operate with different electromagnetic characteristics than those of AEGIS. It can be expected that these characteristics will be chosen to permit the new system to be smaller and lighter in weight than the current AEGIS.

The cost and weight of an AAW system can be further reduced by using a single-face, mechanically rotated radar antenna for three-dimensional air search in lieu of a large four-faced phased-array radar, and by placing the new-technology emphasis on the fire control radar, as discussed in Chapter III. Such a system would use a new-technology agile-beam fire control radar and the interrupted continuous-wave illumination technique discussed in Chapter III to achieve substantial firepower improvements, and would have the advantage of being more readily backfitted into existing ships than could the large phased-array radar system discussed above. 3/ There is, however, no essential incompatibility between "front-end" improvements, such as a large phased-array radar, and "back-end" improvements to missile fire control systems. Both provide needed improvements, and the best capability would be obtained by using both together.

ASW Trade-Offs

In ASW, a ship can emphasize long-range detection and attack with towed-array sonar and LAMPS, or it can emphasize active search and attack with hull-mounted sonar and weapons. Or,

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3/ A currently operating prototype for this kind of system is FLEXAR (Flexible Adaptive Radar), a system being tested under the Navy's Prototyping Program, which incorporates the technology required for the agile-beam illuminator discussed in Chapter III.

as in the case of the DD-963 and the CG-47, a ship can be equipped to do both. Emphasis on active search means installation of the SQS-53 sonar, which has a large impact on ship size and cost. Emphasis on towed-array passive search, on the other hand, requires a LAMPS installation, which also affects ship size, cost, and arrangement. 4/ The choice of emphasis on active or passive search depends upon one's assessment of ASW trends and upon the mission of the ship. A ship intended for inner-screen operations in a battle group would emphasize active search, whereas a ship intended for a broader range of missions might emphasize passive search capability and long-range prosecution with LAMPS.

ASuW Trade-Offs

As discussed in Chapter II, a long-range antisurface warfare capability requires not only long-range antiship missiles but also some means of detecting and targeting enemy forces at over-the-horizon ranges. This can be accomplished with external resources such as land-based or carrier-based aircraft, but the best independent capability is obtained with internal resources such as LAMPS helicopters. The cruise missiles can be put aboard with relatively little ship impact, but LAMPS affects both ship size and arrangement.

There is also the question of whether to put guns on a ship and, if the guns are mounted, whether they are primarily for anti-air or for antisurface/shore-bombardment purposes. Small-caliber, rapid-fire guns such as the 76mm MK75 gun on

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4/ Fitting the ship with the large SQS-53 sonar rather than the smaller SQS-56 would add about 500 tons and $57 million (fiscal year 1982 dollars) to the size and cost of a typical destroyer. Adding the SQR-19 (TACTAS) towed-array sonar would add about 90 tons to the ship's size and about $15 million (fiscal year 1982 dollars) to its cost. Provision of LAMPS helicopter facilities requires a ship size increase of about 375 tons (for hangar, haul-down and handling equipment, electronics, personnel, and aircraft fuel) and results in a cost increase of about $16 million (fiscal year 1982 dollars) over that required for a destroyer without helicopter facilities.

the FFG-7 are best for anti-air or antiship missile defense; larger guns are usually better for antisurface and shore bombardment. 5/

5/ The Naval Sea Systems Command has recently developed a design for a lightweight large-caliber gun that would be especially attractive for the latter functions. This proposed 155mm (6.1-inch) gun would be lighter in weight and have greater range and lethality than the Navy's current five-inch 54-caliber Gun Mount MK45, and would be compatible with the large family of 155mm ammunition available in the existing inventories of the U.S. Army and NATO.

APPENDIX D. DERIVATION OF DDGY DISPLACEMENT AND COST ESTIMATES

This appendix describes how displacement and cost estimates for the DDGY were derived using both the DDGX and the FFG-7 as a baseline.

Incorporating additional combat system or ship performance features into a warship usually increases both the size and the cost of the ship. This is a result not only of the cost and weight of the system components themselves but also of the additional support requirements (electrical power, cooling, additional personnel, etc.) they impose. Similarly, if combat system or ship performance features are deleted from a given baseline, the size and system support requirements of the resulting ship will be reduced and its cost should decrease as well. Using estimates of the total effect on displacement and cost of various features for a typical destroyer, one can derive rough estimates of the ship's size and cost. Such estimates, though useful as a first approximation, are not substitutes for the kind of detailed engineering study upon which firm budget estimates should be based.

Table D-1 derives displacement and cost estimates for the DDGY using the DDGX as a baseline. The DDGX incorporates the latest design practices of the Navy, but, since it is still in the early design stages, its ultimate size and cost are as yet uncertain. It is prudent, therefore, also to derive DDGY displacement and cost estimates using as a baseline a ship that has actually been built and delivered. This is done in Table D-2, which uses the FFG-7 as the baseline.

This analysis yields a DDGY displacement of about 4,900 tons and a follow-on ship cost of $337 million to $428 million per unit. CBO's cost estimate for the DDGY of about $375 million is taken from the middle of this range; the ship's displacement has been rounded upward to 5,000 tons.

TABLE D-1. DERIVATION OF DDGY DISPLACEMENT AND COST USING DDGX AS BASELINE

Feature	Differences DDGY	vs. DDGX	Displacement Effect (Tons)	Cost Effect (Millions of 1982 dollars)
AAW System	New Agile-Beam System	AEGIS-like system	-100	-60.0
ASW System	SQS-56 (Hull)	SQS-53 (Hull)	-500	-57.0
	SQR-19 (Towed)	None	+90	+15.3
LAMPS	Complete Facilities for Two LAMPS III Helicopters	Electronics and Emergency Pad Only	+375	+16.4
Growth Margins	Austere	Liberal	-550	-27.3
Noise Signature	Standard	Quiet	-350	-18.6
Range	10 percent lower	--	-130	-0.7
Gun	New 155mm	None	+36	+10.0
	500 rounds ammunition	--	+29	--
Total Difference			-1,100	-$121.9

Resulting Displacement and Cost Estimate

Displacement (Tons)	
DDGX	6,000
Difference	-1,100
DDGY Displacement	4,900
Cost (Millions of 1982 Dollars)	
DDGX	550
Difference	-122
DDGY Cost	428

TABLE D-2. DERIVATION OF DDGY DISPLACEMENT AND COST USING FFG-7 AS BASELINE

Feature	Differences DDGY	vs. FFG-7	Displacement Effect (Tons)	Cost Effect (Millions of 1982 dollars)
AAW System	New Agile Beam System	MK92/STIR	+75	+10.0
	SPS-48E	No 3-D Radar	+75	+10.0
Missile Launcher	90-cell VLS	MK13 Launcher	+350	+16.0
Speed	30 knots	28 knots	+400	+6.6
Gun	155mm	76mm	+20	+5.0
Range	10 percent higher	--	+130	+0.7
Overpressure	7 psi	3 psi	+100	+3.3
Fragment Protection	Level I	Inherent	+160	+5.5
Total Difference			+1,310	+57.1

Resulting Displacement and Cost Estimate

Displacement (Tons)	
FFG-7	3,600
Difference	+1,310
DDGY Displacement	4,910
Cost (Millions of 1982 Dollars)	
FFG-7	280
Difference	+57
DDGY Cost	337

GLOSSARY

<u>AAW</u>: Anti-air warfare.

<u>AEGIS</u>: New anti-air warfare system developed by the Navy.

<u>ASROC</u>: Antisubmarine rocket.

<u>ASuW</u>: Antisurface warfare.

<u>ASW</u>: Antisubmarine warfare.

<u>CG</u>: Guided missile cruiser designation.

<u>CGN</u>: Nuclear-powered guided missile cruiser designation.

<u>CIWS</u>: Close-In Weapon System; also known as "Phalanx".

<u>DD</u>: Destroyer designation.

<u>DDG</u>: Guided missile destroyer designation.

<u>DE</u>: Destroyer escort designation.

<u>DL</u>: Destroyer leader designation.

<u>ECM</u>: Electronic countermeasures.

<u>ECCM</u>: Electronic counter-countermeasures.

<u>FF</u>: Frigate designation.

<u>FFG</u>: Guided missile frigate designation.

<u>FLEXAR</u>: Flexible adaptive radar.

<u>HARPOON</u>: Intermediate-range antiship cruise missile.

<u>ICW</u>: Interrupted continuous-wave illumination.

<u>IOC:</u> Initial operational capability.

LAMPS: Light airborne multipurpose system; specially outfitted helicopters deployed on surface combatants.

MFAR: Multi-function array radar.

MK32 Tubes: Torpedo tubes for launching antisubmarine torpedoes.

MK99 Fire Control System: Missile fire control system used with the AEGIS anti-air warfare system.

OTH: Over-the-horizon.

PCW: Pulsed continuous-wave illumination.

SAG: Surface action group.

SM-1: Basic version of the Navy's Standard anti-air missile.

SM-2: Advanced version of the Navy's Standard anti-air missile.

SPY-1: Phased-array air search radar used in the AEGIS anti-air warfare system.

SQR-19: Designation for a tactical towed-array sonar system deployed on surface combatants.

SQS-53: Large, hull-mounted active sonar.

SQS-56: Small, hull-mounted active sonar.

TACTAS: Tactical towed-array sonar.

TASM: Tactical antiship missile.

TER: Terminal engagement radar.

TERCOM: Terrain comparison guidance.

TLAM: Tactical land attack missile.

TOMAHAWK: Long-range cruise missile used against ships (TASM) and land targets (TLAM).

TWS: Track while scan.

VLS: Vertical launching system.

V/STOL: Vertical/short takeoff and landing aircraft.